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THE JANUARY SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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THE SCIENTIFIC MONTHLY

JANUARY, 1930

HOW FAR CAN MAN CONTROL HIS CLIMATE?

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FROM the beginning of human history the artificial control of weather and of climate has been of interest to man. It matters not how "perfect" a climate may be; or where man lives; or what specific use he wishes to make of the atmospheric conditions that surround him, there is always something that is unsatisfactory or injurious or disagreeable in what nature provides. It is too hot or too cold. There is too much or too little rainfall. Frost kills crops. Winds are too strong and injure what man has planted. Lightning wrecks buildings and sets them on fire. Hail beats down and may destroy fields of wheat or orchards of fruit. Long-continued cool and cloudy weather retards the growth of crops. Droughts, if they last long enough at a critical time, may cause irreparable damage.

Many absurdly fantastic notions concerning man's control over weather have been, and are still, current. Thus, a western newspaper has lately suggested, it is to be hoped jocosely, that the completion of the new tunnel through the Cascade Mountains on the Great Northern Railway may alter the climate by making it possible for cold air from the continental interior to flow westward through the tunnel. Preposterous as this idea is, it is hardly as hopelessly fantastic as was the view, seriously advanced a good many decades ago, that deforestation on the northern Pacific slope of the United States would change the climate of Europe. The building of railroads and the construction of telegraph lines in the western United States were believed by many people to have brought about a change in the climate of that region, and similar views were held in England when the first railroads were built there. The Mexicans in California are reported to have blamed the Americans for bringing thunderstorms as a result of new railroad construction. Very recently, the world-wide use of the radio has been thought, both in the United States and elsewhere, to have caused unseasonable weather. Professor C. F. Talman, of the U. S. Weather Bureau, has reported that during a summer cold spell in Poland two years ago, the peasants tore down the radio antennae in order to bring better weather. The wide-spread prevalence of this view of an influence of radio on weather was illustrated during the writer's visit in Shanghai last April. While there, he was reported in an interview in a local newspaper as believing that the severe winter over much of Europe was due to the influence of radio. It is hardly necessary to say that he made no such statement. The "interview" was purely a product of the reporter's imagination. Most unfortunately, this so-called interview was cabled to the American newspapers, and was quoted in some of them.

There is always a struggle of man against nature; always the effort to improve what nature has provided. Among the well-known attempts to control cer-

tain features of the weather are the protection of fruit and other delicate crops against frost; the many and varied attempts to make artificial rain, and the method of supposedly blowing a waterspout to pieces by shooting at it. None of these efforts, it should be observed, is directed at a complete control of all the weather elements. All of them concern individual phenomena only. Mark Twain was hardly correct when he wrote his often-quoted statement, "Everybody talks about the weather but nobody does anything about it." For century after century man has been trying to do something about it. But he is dealing with an immense atmosphere, unconfined, free to move—a physical laboratory in which experiments on an enormous scale are constantly being performed. There can be no hope, and no possibility, of exercising any control over this vast atmosphere as a whole, or even over any considerable part of it. The most, and the best, that man can ever hope to do is to deal with a very small part of it, over a very limited space at best. The fundamental processes of nature, in her great atmospheric laboratory, are concerned with many cubic miles of air. As Sir Napier Shaw has well expressed it, "We are lords of every specimen of air which we can bottle up or imprison in our laboratories. . . . In the open air we are practically powerless."

It is convenient and logical to consider man's attempts to deal with his weather and climate under three heads, or stages. These are, first, protection; second, prevention, and third, production. The first stage is perfectly passive. No attempt is made to change the normal order of nature. Man simply seeks to protect himself or his crops against what comes. The second stage is more active. In this it is sought to prevent conditions from occurring which are undesirable or injurious. The third stage is the most active and aggressive of the three. In this man definitely and seriously tries to produce something which is not otherwise present. He plans a campaign to bring about a result. He attempts to create a weather condition which nature does not herself, in her ordinary normal régime, produce.

In the first stage, the passive one, there is neither prevention nor production, but only protection. Here man accepts things as they are. He merely tries to shield himself against them. In this group of illustrations we have man's many methods of providing himself with shelter, ranging from the most primitive, such as the rock caves of early man, or the simple bamboo and palm-leaf huts of the tropics, to the most elaborate modern houses and other buildings, heated in winter in cold climates and without doubt more and more in the future to be artificially cooled during the heat of summer. An immense amount of time and of inventive skill has been expended in making this protection more and more adequate.

Tropical cyclones are among the most dangerous phenomena with which man has to contend. They devastate large areas, destroy crops, wreck buildings and often cause great loss of life. With an increasing population in the districts visited by these storms, and with the growth of cities and of industrial plants there, better methods of building are becoming more and more necessary. It is clear that man can do a great deal towards promoting the safety of human life in, and lessening the damage wrought by, tropical storms. Building regulations in the regions visited by hurricanes and typhoons should certainly take cognizance of these facts. Buildings can be constructed of heavier materials, such as reinforced concrete; roofs can be "tied on" more firmly; the foundations can be made more secure, and the structure be more firmly united with the foundation. Locations should be selected beyond the reach of the storm waves which cause most of the fatalities.

Cities on the coast can be protected by sea walls and by breakwaters, to lessen the dangers of floods resulting from the inrush of ocean waters. Inland settlements can be protected against the fresh-water inundations which so often follow the torrential rains.

In the case of tornadoes, the most violent disturbances in the atmosphere, tornado cellars provide adequate protection to life. Recent studies have shown that solid steel and concrete construction will resist the violence of ordinary tornado winds better than structures of brick or wood, although it is practically certain that no building which is exposed to the greatest fury of the winds or which passes through the center of a fully developed tornado will stand up, at any rate without very serious damage.

Protection against lightning is another aspect of this phase. We have advanced very far beyond the stage of fifty or more years ago, when the "lightning-rod man" traveled about the country, installing the old-fashioned tall rods on farmhouses and barns. The modern methods of lightning protection have been very carefully worked out. The general idea is to enclose the building in a wide-meshed metal "cage," so to speak. The ridge-poles, chimneys and other elevated portions of the roof are connected by copper, galvanized iron or steel wires or cables. At several points there is connection with damp ground. The purpose is twofold: partly to prevent the disruptive discharges of electricity which we call lightning, and partly, if a bolt hits the building, to conduct it safely by an easy path to damp ground. Protection against damage and danger to human life when a lightning bolt hits a building belongs in the first stage, the passive one, when protection, not prevention or production, is the motive.

Frost protection is another illustration. Here no attempt is made to control the general conditions that bring the low temperatures associated with frost, but by means of cloth or other screens, or by the use of smoke clouds from fires, we try to protect sensitive crops from damage by checking radiation from the ground and the plants. The cloth screens over the tobacco in the Connecticut Valley, similar screens used in certain Mediterranean districts to keep fruits from ripening too fast and so to have them ready for market at the most favorable time, and planting coffee trees under the shade of other trees, such as bananas, in order to protect them from the tropical sun, are additional examples.

The planting of trees to serve as windbreaks is a characteristic undertaking on our western plains, and in many other places in different parts of the world. These windbreaks do not prevent the conditions that give rise to the high winds which are injurious to planted crops. They merely protect the crops on the leeward side by reducing the wind velocity. Studies of the climatic effects of such windbreaks show that, incidentally, there is some reduction of evaporation and a slight local moistening of the air. The high walls seen in many places in the Mediterranean countries of Europe are built to serve as protection against the strong winds of that area. These walls do not add to the traveler's enjoyment when he is anxious to see the gardens and orchards, but they serve their purpose satisfactorily and are excellent examples of man's efforts to secure protection against unfavorable climatic phenomena. Those who have journeyed through the lower Rhône Valley can not have failed to observe the rows of trees planted there to serve as windbreaks against the dreaded mistral, a strong northerly wind often reaching gale force, which has much in common with our northwest winds here. The mistral is the "master-wind" of that section of the northern Mediterranean coast. It is well known, and commonly

spoken of as one of the scourges of Provence. On our own western plains, the desiccating effects of hot winds during the summer, often seriously disastrous to growing crops of all kinds, can be decreased by windbreaks planted on the southern margins of the cultivated fields, while rows of trees on the north reduce the velocity of the cold northwest winds of winter and are a protection to the otherwise fully exposed farmhouses. Windbreaks, on whichever side of the buildings they are planted, furnish shade in summer and break the monotony of the great level open stretches of the plains.

The narrow streets of cities in the Near East are familiar to us all. They are designed to keep out the sun, and are often, in shopping districts, covered by awnings to serve as additional protection. In this country, in various cities, there are arcades lined with stores, and shoppers are thus protected from inclement weather. One of the advantages enjoyed by large department stores is the fact that so many different things can be purchased under one roof, without the necessity of going out when weather conditions are unfavorable. A rather amusing investigation has recently been made of the effects of rainy days upon the amount of business done by the larger department stores and by the smaller shops. It appears that if the day begins by being fine, but has rain about noon and in the afternoon, the department stores are the gainers and the smaller shops are the losers. The apparent explanation is that shoppers, especially those from the outlying suburbs, start to town on a fine morning, but if the afternoon is rainy or snowy, they naturally prefer to stay under one roof, and therefore do their purchasing in one store. On the other hand, if the day begins by being very cold or wet or disagreeable, both department stores and the smaller shops suffer loss of trade.

We turn next to the second stage, that of the effort towards prevention of conditions that would otherwise occur. This is, obviously, more active and aggressive than the first step, that of mere protection.

The campaign against frost goes back to early days, and is carried on wherever temperatures fall low enough seriously to damage valuable crops. "Frost-fighting" is the term that has come into use in recent years in the United States, and it is a very appropriate designation for this aspect of man's struggle against nature. Nowhere in the world has frost prevention been more thoroughly studied than in our own country. Nowhere else is the campaign carried on more scientifically or with so large an investment of capital. To-day's fight against frost is a carefully planned and an effectively organized undertaking. It is no longer the haphazard burning of piles of brush, straw and other rubbish, as in former times, when the formation of a thick cloud of smoke was the object sought. There were then no regular frost forecasts. There was no cooperation among neighboring farmers and fruit-growers. To-day, in this country, the Weather Bureau pays special attention to its general forecasts of frost during the critical times of the year, and in addition in many of the great fruit districts of the west special local observations are taken and used as the basis of local forecasts. Cooperation between fruit-growers in the same locality insures far greater safety to all than is the case when a single orchard or ranch is protected. It is a common fight against a common enemy, and is a cooperative campaign.

Frost-fighting may be seen in many parts of the country, and the methods used vary. In the cranberry bogs of the Cape Cod district of Massachusetts flooding is the natural, easy and most effective means of preventing frost damage. In the citrus belt of Florida, in the cranberry bogs of Wisconsin, in the famous apple district of southern Oregon, in many other districts and in the case of many other crops, the campaign against

frost is waged. But it is in that wonderful citrus fruit district of Southern California, in the general vicinity of Los Angeles, that the prevention of frost is most widely and most scientifically carried on. The climate of Southern California probably comes as near perfection as a climate can come, but there are some things, even in Southern California, that man would prefer to have changed. Frost is a potential factor of very great importance, relatively infrequent as it is. Where immense sums of money are invested in citrus fruits and in other crops, the prevention of frost becomes a necessity.

Many different methods of frost prevention have been tried, as by "smudges" of dense smoke from moist bonfires; by dampening the air, either by means of sprayers placed above the tree-tops, or by allowing steaming warm water to run through the irrigation ditches and channels; by keeping the lower air in motion, or bringing down warmer air by means of huge fans or blowers, and so on. The result of experience and of much careful experimental study has been to show that the safest, best, most effective and, in the long run also the most economical, plan is to use orchard heaters, burning crude oil. On a clear winter night, when the forecasts indicate frost occurrence, many thousands of these heaters are burning, and the sight, to those who are not accustomed to it, is one that will never be forgotten. It may be asked, "How is it possible, even with thousands of oil heaters, to keep the temperature outdoors above the danger-point?" The answer is that frost occurs on calm, or fairly quiet nights; the coldest air is near the ground, and only a comparatively thin layer has to be heated. If frost came on very windy nights, the air warmed by the heaters would be moved away, and cold air would continually be brought in. Under such conditions, any general warming of great masses of moving air would be impossible. It is the relative stagnation of the lower air on frosty nights that makes orchard heating practicable.

The expense of any such frost-fighting campaign is heavy, and includes the cost of the heaters, the fuel and the wages of the men who fill and tend the heaters. Therefore there is a limit to the number of times a winter that frost-fighting is worth while. It is not profitable if it has to be resorted to often. As a result of the vigilance of the growers in watching the readings of the thermometers in their orchards, and of the effective frost warning service of the Weather Bureau, the expensive application of the heating process can be so accurately planned for as to avoid a great waste of oil on the one hand, and the destruction of the crop on the other.

Hail is another climatic handicap whose coming man has often tried to prevent, for it may cause very serious damage to crops of all kinds. Various sorts of religious emblems or amulets are still hung on the trees by European peasants in the belief that such charms will prevent hail from falling. In Europe, for many generations, these and many other methods have been tried, from the ringing of church bells in the earlier days down to the "hail-shooting" and so-called "electric Niagaras" of modern times. "Hail-shooting" is still popular in some of the vine-growing districts of southern Europe. Here especially designed mortars are used, from which, when threatening thunder-clouds are approaching, charges of gunpowder are exploded towards the storm. There is much noise; vortex rings of smoke rise from the mouth of the mortar—and the hail falls, or not, as nature ordains. An enormous amount of money has been spent on this hail-shooting campaign. Special foundries have cast the mortars. And the belief persists that the firing is effective. Hail is the product of violent ascending and descending currents of

air in thunder-storms. These currents may rise, at considerable velocities, for thousands of feet. The explosion of charges of gunpowder on the earth's surface can not alter the condition of the great physical experiment which nature performs every time she produces a thunder-storm. Fortunately for man, hail does not occur in every thunder-storm, as common observation will show, and fortunately also, when it does occur, it falls over narrow strips of territory only, and never throughout the whole district covered by the storm. The so-called "electric Niagaras," or "hail-rods," are tall openwork steel or iron towers, erected in certain districts of Europe with the idea that they will in some way draw off the electricity from the clouds and prevent the formation of hail. The electricity developed in a thunder-storm does not affect the formation of hail; nor have the "hail-rods" any influence, one way or the other.

In speaking of protection against lightning as an example of the first stage in man's effort to control his climate, the fact was noted that modern methods are designed to protect buildings, when disruptive discharges of electricity occur, by providing a natural and easy path to the ground. The modern "cage" method has a second object, and that is to prevent as many disruptive discharges as possible by the flow of electricity from the ground up through the "cage" to, and then off from, the points on the roof. Excessive charges of electricity and flashes of lightning may thus be prevented.

Fog is another climatic element which is often a very serious handicap to man. In fact, with our present universal use of automobiles and trucks, and especially with the rapid development of aviation, fog is every day assuming greater importance as a factor in our activities. To prevent the formation of fog, or to dispel it when formed, various methods have been tried. In the laboratory, with small blocks of fog, the air can be cleared by electrical discharges, or by heating it and thus increasing its capacity for water vapor so that the water particles will disappear. But in the open air fog prevention is a very different matter. Within a few years experiments have been carried out in Pittsburgh with a view to preventing the formation of the river fogs which are there a serious handicap and menace to navigation. Oil was poured on the river, and the results, while not convincing, seem, within limits, to have had a slight degree of success. In France, coating the waters of the Rhône and of the Saône at Lyons with oil has not proved a practicable undertaking. The "steam" type of fog occurs on calm cool nights when the water in the river is warmer than the air above it. The warm air, rising from the water, contains much water vapor, and is chilled when it mixes with the colder overlying air. By mixture and conduction the cooling may be sufficient to bring about condensation into fog. The oil film serves in a way as a sort of cover or lid, and checks, to a certain degree, the "steaming" from the warm water of the river. This method is, however, applicable, so far as it is successful at all, to one type of fog only. It could not be used in the case of the common lowland and valley radiation fogs that form so often on clear, quiet nights, especially in autumn and winter, over the lowlands and in the valleys of a mountainous or hilly country.

Many fogs result from the cooling of the lower air which comes from a considerable distance and whose moisture is also derived from a distance. When such warm, moist air happens to be carried over a cold surface, it may be water or land, cooling takes place and condensation may result. Local evaporation over the locality where such fogs occur is not the cause of the fog. The warm

air brings the moisture with it. Of this type are the famous and much-dreaded fogs of the Grand Bank of Newfoundland, so familiar to transatlantic travelers over the northern steamship lanes. These fogs are mainly due to the importation of great masses of warm, moist air from over the warm waters of the Gulf Stream drift. As this air crosses the cold water of the bank it is chilled, and condensation into fog results. Unfortunately for navigation, the Newfoundland Bank area of the North Atlantic has almost ideal conditions for fog formation, especially in the spring and early summer. The causes of these fogs are far and away beyond man's control. Unless, or until, some way is found for locally dispelling the fog in the immediate vicinity of a vessel, the situation must remain as it is to-day, and always has been. It is true that experiments have been made in fog-dispelling on board ship by means of powerful electrical discharges, but however successful such a temporary local clearing of the air may be, the fog constantly keeps blowing in, and any cleared space is inevitably almost immediately again foggy.

In this country experiments have been made with a view to artificial dissipation of fog on flying fields by means of electrified sand dropped from aeroplanes. While the early press reports of this undertaking were favorable, there are several points concerning which conservative meteorologists are still in doubt. Electrified sand does seem to have cleared spaces in clouds, but on the other hand "holes" in clouds often develop normally in the processes of cloud formation and dissolution, and ordinary aeroplanes can clear a space through a thin cloud without the use of electrified sand. Whether reasonably successful or not, the practical fact remains that fog-dispersal by means of electrified sand scattered from aeroplanes is not a feasible method in the case of extended dense fog sheets, and the expense on a large scale is prohibitive. It is, at any rate at present, inconceivable that any general dispersal of such a fog as, *e.g.*, that which at times lies over New York harbor, can possibly be accomplished by this method. Electrical dispelling of fog on a small scale, both in the laboratory and even outdoors, can be accomplished. It is the magnitude of the task outdoors, and the expense of it, that stand as stumbling-blocks in our way at present.

In Europe, where commercial aviation began on a large scale earlier than it did in the United States, local studies of practical methods of fog dispersal on flying fields have naturally outstripped our own efforts in this direction. In England, for example, various methods have been tried, all on a relatively small scale, however. Heating the air, in order to increase its capacity for water vapor and thus bring about a clearing away of the water particles, has proved impossible. Keeping the air in circulation by means of large fans and blowers, and thus endeavoring to prevent the occurrence of a low-lying layer of cold air essential to the formation of an ordinary lowland or radiation fog, was also found to be impracticable, as was the attempt to drain fog-laden air off of flying fields. Experiments in fog-dispersal by means of electrical discharges and by explosives have not been decisive. So far, all the attempts to dispel fog by artificial means except on a small scale, and when all the circumstances are favorable, have proved unsuccessful. It is possible to dispel fog, but all methods thus far employed are too expensive and could not be employed on a large scale outdoors. The general problem of fog prevention and of its dispersal when formed remains for the future.

The third stage in man's efforts to control his climate and weather is the

most active and aggressive. In this, there are the attempts to produce a condition which is not present as the ordinary result of natural processes. We are here concerned, not with protection or prevention, but with production.

The artificial production of rain is doubtless the most wide-spread and best known of man's activities in this direction. Over much of the earth's surface rain does not fall in sufficient amounts, or at the proper seasons, to satisfy us. Rain seems to fall so easily when it does come, and clouds, which precede rainfall, are so common and seem to be so very close to the stage of rainfall, that it would appear a relatively simple matter to produce clouds artificially, or, if they are already present in the sky, to shake the rain out of them. For clouds, it must be recalled, are merely collections of millions of small water droplets, or of ice crystals. The question whether any precipitation takes place depends on the size, that is the weight, of the solid particles, and upon the possibility of their being able to fall through the rising currents of air which usually accompany cloud formation.

One of the popular aspects of this whole matter concerns the very common belief that battles produce rainfall, it being a general impression that in some way the heavy cannonading brings about precipitation. In all recent wars, this belief has found expression. During our own Civil War, in the Franco-Prussian War, during the World War, the opinion was expressed, over and over again, that rains followed battles, as effect follows cause. During the great war the question was often asked by highly intelligent people whether long spells of rainy weather here in the United States were not due to the war in Europe. And in England, not many years ago, certain agricultural organizations sent a communication to the British Admiralty, asking that the heavy gun firing during the regular autumn naval maneuvers in the channel be discontinued on the ground that it brought rains during harvest time. It is an interesting fact that, while in modern times, in the days of gunpowder and of other explosives, the cause of the rainfall has been sought in the heat and shock of the firing, the ancient Greeks, long before the days of explosives, also believed that fighting brought rain. They attributed the occurrence of precipitation to the moisture from the perspiring bodies of the troops. It was only in relatively modern times that gunpowder explosions were believed to be responsible. The fact of the matter clearly is that preparations for battle have usually been made during spells of fine weather, and the fighting generally begins while it is still dry. Then, in the ordinary course of events over most of the temperate zone, a few days of fine weather are followed by a general rain storm; the battle ends in, or may be closely followed by, rain. The origin of the popular belief is thus easily explained.

Two main lines of attack on the problem of artificial rain may be noted. One attempts to produce rainfall by means of explosions; the other has sought to produce rain-clouds by making fires. With the former method we have had a most humiliating experience in our own country. About forty years ago, as the result of successful political wire-pulling on the part of one individual, who was not a scientist, Congress was induced to make an appropriation of several thousand dollars for the purpose of making rain in Texas. The method used in these experiments was mainly to send up explosives by means of small balloons, and then to have the explosion take place at the cloud level. It was claimed that the shock of the explosions and the liberation of gases from the balloons would produce the rain. The re-

port, which, to our national disgrace, was printed as a Senate Document, was naturally highly optimistic. Rain was stated to have been produced on numerous occasions, and Congress was induced to make a second appropriation for another year's campaign. By this time, scientific men were becoming aroused, and a competent meteorologist representing the Smithsonian Institution accompanied the rain-making expedition. As was to be expected, his report was very different from that of the leader of the undertaking. It appeared that all that the explosions did was possibly to shake down a few drops of rain a little in advance of the time at which they would have fallen naturally, and that the general rainfalls which it was claimed resulted from the experiments were such as would have come in any case. This most unfortunate undertaking, sponsored by the Congress of the United States, did much to discredit us in the eyes of European scientific men. It is highly important that no such occasion should arise again.

The development of the typical cumulus cloud of fine summer days has long been known to result from the ascent of air warmed near the earth's surface—rising when lighter than the overlying air; cooling as it ascends, and, if sufficiently cooled, reaching its dew-point so that condensation takes place and the cloud appears. Each cumulus cloud is in reality "the visible top of invisible ascending currents of air." These fine-weather summer daytime clouds, with their familiar flat bases and great convex tops, are characteristic over well-warmed land surfaces. Water, being warmed much less than land under the summer sun, is therefore not, as a rule, favorable for the development of these clouds, although, near shore, they drift out over the ocean and in a different and much less massive form they are characteristic of the trade-wind belt at sea. It is an interesting fact that occasionally, when conditions are favorable, the hot air rising from fires may produce small, and sometimes even fairly large, cumulus clouds. I have myself seen beautiful illustrations of this in the case of the burning coal pockets of the Boston and Maine Railroad in Charlestown some forty years ago, and over a brush fire in Peru in 1897. Such clouds were well observed during the fire which followed the San Francisco earthquake, and they are not infrequently reported as forming over burning oil-wells.

About the middle of the last century, Espy, one of the greatest of American meteorologists, who was especially interested in storm formation by convectional ascent of warm air, seriously suggested that showers might be produced artificially, during summer droughts, if the farmers in the United States would unite in building huge bonfires of rubbish, or in burning large areas of woodland. In this way, Espy maintained, considerable masses of warm air would rise; cool during their ascent; form cumulus clouds, and finally reach the stage of rainfall. A story is told of an amusing incident in this connection. A party of engineers was constructing a road in a southern cane-brake. The day was intensely hot, and the negro laborers refused to work. The engineers said that if work was stopped, they would make a thunder-storm. The cane-brakes were set on fire, clouds formed, and, so the story goes, in a short time a small thunder-storm was in operation. The laborers were so much frightened because of this supernatural power on the part of the engineers that no further trouble was experienced.

In recent years there have been numerous so-called "rain-makers" who have plied their trade and often made large profits by contracting with farmers during a dry season to produce rain in return for a financial consideration.

The contracts are for so much money per inch of rain. These "rain-makers" are, of course, pure fakirs. They usually build a small wooden shack in some rather inaccessible locality, and from the roof smoke rises when the rain-making process is going on. The whole business is a distressing and disgraceful performance. Yet the surprising thing is that so many apparently intelligent farmers, in the western United States, in Canada and in Australia, have, even in very recent years, been hoodwinked. The "rain-maker" usually has sense enough to watch the official weather maps and forecasts carefully from day to day. If he sees that the general weather conditions are becoming favorable for rain he produces his contract, secures his clients' signatures obligating them to pay so many hundreds or thousands of dollars for an inch of rain, and appeals to them with the slogan, "No rain, no pay." It is an easy financial proposition for the "rain-maker." In a *Science Service* note, Professor C. F. Talman has called attention to an interesting suggestion made by Dr. David Starr Jordan which is directed towards positive assurance of the rain-maker's financial status. The rain-maker contracts to bring rain within a certain time, for a fixed sum. He should then take out weather insurance against a continued dry spell during that time. If the rain comes, the farmers pay. If it does not come, the insurance company pays. "Assuming the insurance premium to be less than 100 per cent. of the face value of the policy, and also less than the amount to be paid for rain by the drought-stricken farmers—conditions that probably could be met in most cases—the scheme is absolutely perfect."

On quite a different basis from all such attempts at rain-making by pure impostors are the scientific experiments with electrified sand, already referred to in connection with the fog-dispersal. It has been claimed that this method not only dispels the fog, but, by causing the small water droplets to join, produces rainfall. Here again, what may work as a laboratory experiment, or on a very small scale outdoors, is hopelessly inadequate to produce any large result. Professor W. J. Humphreys, of the U. S. Weather Bureau, has discussed this matter very clearly. The physical processes at work in bringing about our general rains are on an immense scale, and involve great masses of air, many cubic miles in extent. Our great storm clouds are produced by the forced ascent of immense masses of air. The water vapor is imported, often, from great distances. Producing larger drops in place of smaller droplets, locally, is not the line of attack for any effective result. Even small drops will fall if the ascending currents of air are weak and slow. Our general rains result from cooling, and continued cooling, of masses of air imported from a distance, and not from any local cause. Even if we could bring down, as rain, all the water in a great cloud mass overhead at any one moment, the resulting precipitation would be practically negligible. The experiments of nature which give the earth its beneficent rains are on far too vast a scale for man to deal with.

A very recent attempt to make rain was reported in a press dispatch from Hong Kong, June 15, 1929. That city was suffering from a serious water famine. The Royal Aviation Force and other agencies were to cooperate in trying to produce rain. "Two aeroplanes will ascend," so the dispatch read, "above the clouds and sprinkle a powdered chemical with a refrigerating effect, which it is hoped will precipitate the downpour." A later dispatch reported the attempt as unsuccessful.

Here we touch also the much-debated question of the influence of forests on climate, and especially on rainfall. If

man, by reforestation, can increase rainfall, he can in this way produce a change in his climate. This question is one of very long standing. For generations, at least as far back as the time of Columbus, the belief has been held that forests exert far-reaching effects upon climate, and that, therefore, deforestation, whether as the result of man's own efforts or because of fire, will bring about marked changes in climate. This popular notion gained great support in Europe at the time of the French Revolution, when there was a wide-spread destruction of the forest trees. So exaggerated have been some of the ideas on this matter that, as was noted earlier in this article, writers have seriously maintained that the cutting down of trees on our northern Pacific coast has affected the climate of Europe. Of course, no intelligent person has any such idea today. Forests are merely one kind of surface cover, and while the climatic conditions within an extended forest may be slightly different from those in open country not far away, it would be preposterous to suppose that a forest climate, if there is such a thing, can be transported to a distant region.

The reason for the world-wide prejudice as to forest influences is somewhat difficult to determine. It is likely, however, that because forests are usually found in regions of fairly heavy rainfall, it has seemed that the forests produce the rain. The world's forests do grow where the rainfall is greater than it is over the grasslands and the deserts. Furthermore, forested areas are as a rule found where the humidity is higher, where there is more cloud and where the temperatures are somewhat less extreme.

In dealing with this question, the historical method of treatment has in the past been very generally adopted. A forest once existed in a region where now there is no forest. Tradition, or historical record, establishes that fact. In this same region the climate is not what it once was. People say so. It is universally accepted as beyond a doubt true. Hence, the removal of the forest produced the change in the climate. This is a fair outline of the general run of the historical argument. Nothing here is clearly and beyond a doubt established. Especially in the case of a supposed change of climate, there is no instrumental record to prove it. Everything is vague and uncertain—scientifically wholly worthless. The literature on the forest-climate problem is a very extensive one. It is interesting because of the extraordinary variety of opinions which it includes and because of the unreliability of the evidence upon which the conclusions are based. Except for its value as an historical survey, all the writing on this subject is negligible until the last few years.

Clearly, no student of climate will, or should, be satisfied with any evidence in this matter that does not rest upon accurate instrumental records. Tradition, hearsay, even historical records, are negligible. The whole controversy in regard to forests and climate has, within the last few decades, entered upon a new phase. The increase of meteorological stations all over the world has brought us instrumental records not available in the earlier days of this great controversy. Furthermore, in Europe especially, but also in India, in Java and elsewhere, stations have been established under the forest trees, in forest clearings and in open country surrounding forests, for the express purpose of comparing the conditions in forests and elsewhere. In addition, the climatic effects of deforestation and of reforestation have been studied by the most approved modern methods, under the supervision of competent scientific observers and in connection with official meteorological organizations. Upon such instrumental records, and upon

them alone, does the climatologist rest his case. The speculations of former times have been discarded, interesting as many of them were. We now have enough definite information to enable us to state certain well-established facts. What are these facts?

First, as to temperature. The observations indicate very clearly that, in temperate zone forests, the average temperature for the year is slightly lower, a degree or so Fahrenheit, than that over open land near by. In summer, forests are a few degrees cooler by day, probably chiefly because of the decreased evaporation and not because of the shade, and they are somewhat warmer by night. In winter, minimum temperatures in forests are a little higher than those in the open. Some observations in Arizona and New Mexico show that all extremes both of heat and of cold are somewhat modified under the forest trees. The differences as regards temperatures are clearly very small. In connection with this matter we should remember that the temperatures that we feel—the so-called "sensible temperatures"—by no means correspond directly to the temperatures as recorded on thermometers. We are affected, in our sensations of heat and cold, by many factors that do not influence the thermometer, such as conduction, radiation and evaporation, as well as by our physical condition, our clothing, exercise, and so on. When we leave a hot dusty road on a summer day and walk through a forest we have an agreeable sensation of finding it cool, but it is not a lower air temperature that affects us. It is the fact that we are in the shade. Again, on a cold, raw, windy day, forests seem much warmer than the open, but this apparently higher temperature is not indicated by the thermometers. It is due chiefly to the fact that we are out of the wind and are therefore losing less heat by conduction. The actual temperature differences between forests and the open are, as has already been indicated, slight. They are, in fact, too small to be felt, in most cases. Our sensations are not reliable indices to actual temperatures.

As regards relative humidity in forests, the results of observation show clearly, as is to be expected, that the air under the trees is somewhat damper (from 5 to 10 per cent. on the average) than that in the open, and that evaporation is less, doubtless chiefly because of the decreased wind movement.

The crux of the whole forest-climate controversy is in connection with the possible effects of forests upon rainfall. Temperature, humidity and evaporation are but minor, perhaps almost negligible, factors. Here again the climatologist rests his whole case upon the results of observations, provided those observations are made with accurate instruments, under proper supervision and exposed in accordance with established rules. Such observations are available for several European areas. Unfortunately, our own country is far behind Europe in this whole investigation. All the earlier cases in which there were apparent evidences of considerable influences of forests upon rainfall have been discarded because the records were unreliable. The best European rain-gauge records now available indicate that forests do have an effect in increasing the rainfall, but only to a very slight degree. It is true that the rain-gauge readings in and close to forests show an excess of between 2 and 10 per cent. of the annual rainfall as compared with open fields near by, and also indicate a slight increase as the result of reforestation. But careful checking of the observations shows that much, or most, of this difference is due to the difference in the exposure of the gauge, and when allowance is made for such instrumental errors, the increase in the local rainfall

due to the forest is not more than 1 or 2 per cent. This is, obviously, an almost if not entirely negligible effect. There are those who believe that further observations are unnecessary, and consider the case closed. The majority of climatologists, however, are anxious to have many more observations, especially in the United States and in the tropics, for up to this time we in this country have contributed little toward the settlement of the controversy, and there is need of additional data from tropical forests. The forests of Arizona and New Mexico, where some observations have been made, seem to have no appreciable influence on precipitation. At Marietta, Ohio, there are rainfall records extending back about one hundred years, to a time when that district was forested. Yet the average precipitation of the first fifty years was less than 1 per cent. greater than the average of the last fifty years.

A conservative view of the whole situation would seem to be this. The question of the climatic effects of forests is still, to some extent, an open one. The available instrumental observations indicate slight effects, on temperature, humidity, evaporation, wind movement and rainfall, but the instrumental data are still few. It may be, although this seems very unlikely, that more widespread and more complete observational data will somewhat change the situation as it appears to-day. One thing is, however, clear. The extravagant claims made by various writers in favor of forest conservation and of reforestation on the ground that forests have a very marked influence in increasing rainfall have no support in the available observational results. This does not mean that we should not develop our national forest conservation policy, or that forests have no effect upon erosion and floods. The relations of forestation and of deforestation to run-off, erosion, high and low water and similar problems do not directly concern the climatologist. His immediate responsibility ceases when he honestly states his conclusions regarding forest influences on climate. There seems to be no possibility of definitely establishing, or of definitely disproving, the contention that deforestation on the southern Appalachians must bring about a decrease in rainfall over the eastern half of the United States. We are here dealing with the conditions of immense masses of atmosphere, over great distances, without the possibility of instrumental record. The conservative view, based on known facts of forest influences elsewhere, would seem to be against any appreciable effects of the kind here referred to.

There is one other effect of trees upon moisture to which reference may be made. This is not a case of increasing rainfall, but of collecting water droplets already in the air, as the result of a general process of condensation with which the trees have nothing whatever to do. What I have in mind takes place where fogs or clouds drift through or are present among trees or bushes. In such cases, the leaves and twigs may catch and collect the water droplets to such an extent that there is actually a fog or cloud drip to the ground underneath the trees. Numerous cases of this kind are well known. In the dry summers of California, for example, in the coastal fog belt, the fog drip may often be seen, and serves to keep the soil damp and the vegetation green in the immediate vicinity of the trees. Thus, in the redwood district, on the immediate coast, the trees are often so wet that the fog-drip is like a very light rain. The vegetation on the hills of Berkeley shows similar, but less marked, effects. Table Mountain, near Cape Town, when covered with a cloud, has a well-known "cloud-drip." Other cases have been

described by numerous writers on Green Mountain on the island of Ascension, and in the Hawaiian Islands. The "rain tree" of Ferro, about which many stories have been told, doubtless is to be explained as a case of fog-drip, and the "dew ponds" of the English downs are kept wet not by dew but by fog-drip. Such effects, it should be noted, are very local, occur only where the necessary elements of fog or cloud and of trees or shrubs are present and are not world-wide although they do have a certain local importance.

The question: How far can man control his climate? is, then, briefly answered as follows. We can, here and there, by methods developed as the result of experience and of study, protect ourselves against or prevent the occurrence of certain conditions which are disagreeable or dangerous to us, or are injurious to our crops. We can not produce rain, or change the order of nature. But where we have succeeded, as in frost prevention, for example, the results are of very great economic significance. That the future will bring further advances in the way of controlling local climates is certain. There is no hope, however, of our ever being able to bring about any but local modifications. To repeat Sir Napier Shaw's statement: "We are lords of every specimen of air which we can bottle up or imprison in our laboratories. . . . In the open air we are practically powerless."

FRONTIERS

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AFTER writing *Frontiers* at the head of my first sheet I recalled that this was also the title of Lord Curzon's Romanes Lecture delivered about twenty-two years ago to the young men of the ancient University of Oxford. Lord Curzon spoke of geographic and political frontiers, and urged the young men of Oxford to take their part in the responsibilities of the wide-flung boundaries of the empire. It is more fitting and more pertinent to the present needs of our American civilization to consider the frontiers of science.

As a background for a discussion of the frontiers of science it is proper to recall that the geographic frontier has been until recently the most ever-present and compelling reality of our American history. It is significant that Lord Curzon lays almost equal stress on the frontier as a factor in English history.

While Lord Curzon's vast colonial experience has led him to treat his problem much more as an American might have done than would have other European writers, there is nevertheless an unmistakable difference between his treatment of the frontier and that which would be accorded the same title by an American. May I suggest that this is due to a difference in the European and the American conception of the frontier? In Europe they cross the frontier. In America we penetrate the frontier. In Europe they think of the defense of the frontier. In America we plan for its development.

To the American the term frontier suggests no specific geographic boundary, for the great frontier line has been constantly shifting. Instead, it calls to mind the musket, the rifle, the pack saddle and the canoe, the deep woods and the open prairies, the fields of frosty snow and the sands of heated deserts, the seemingly limitless plains and the seemingly unending defiles of rugged mountains. Above all it recalls the frontiersman. To the American the term frontier implies the borderline between what is known and what is unknown. It can not be conceived of apart from those hardy, fearless and independent men who penetrated the wilderness and who by their daring made possible the development of a west and the regeneration of an east that was approaching decadence.

To be sure, the frontier long ago moved beyond the gaps of the Appalachians, and the regions lying to the east of these barriers have largely ceased to be conscious of the influence of the old frontier, notwithstanding the fact that they are in no small degree dependent physically and intellectually on the new west which has so swiftly replaced the old frontier. Even west of the Mississippi it is, in our day, only the botanist, the zoologist and the geologist who have the privilege of seeing with their own eyes something of the life of the old frontier, yet in a large way the forward movement of the frontier may be said to have until recently dominated our national life.

I have referred to the development of the west because in America the great frontier movement has been to the west. In a way "the west" has, indeed, been synonymous with "the frontier." The full magnificence of the great westward movement can be realized only when we recall that the statement that the movement has been toward the west is true only in the average or statistical sense. In detail, the movement was most com-

plicated. Along the St. Lawrence and over the Great Lakes the French pushed their canoes to the valley of the Mississippi and, with a line of outposts, cut the continent in two. In the southwest the Spanish had established their settlements on the Rio Grande and Gila and on the southern Pacific coast. In the northwest Russia had secured a foothold and had laid claim to a part of what is now California. Hence the venturesome vanguard of the English-speaking people of the Atlantic seaboard had in its westward movement to cut and to obliterate the frontiers established by those who differed in race, language and religion. The great human tide of frontiersmen moved forward not merely over geographic barriers, against the force of great biological obstacles and against the resistance of primitive men, but also against the opposition of social and religious prejudices engendered of historic political differentiation. This cutting and obliterating of old frontiers by the great westward movement has furnished some of the most thrilling chapters of our national history.

The westward flow of the human tide and the transformation of our great continent have been so rapid that the most of us have not yet realized its full significance. As compared with most of the changes with time in history, it has been almost instantaneous. The swiftness and magnitude of the transformation may be grasped when we contemplate the western half of our continent as we see it to-day, and then recall that as late as the early years of the nineteenth century many thoughtful writers considered our possession of the entire trans-Mississippi region as important primarily because it would protect the habitable region to the east against the encroachment of some rival power.

This may seem to be history, not science. It is not, however, foreign to my present theme. The development of our vast American wilderness has been due in part to the hardihood of our frontiersmen of exploration and our pioneers of settlement. In large part it has been due to the application of the results of the research of frontiersmen of science.

Geographically, our western frontier has passed into history. Intellectually, the passage of the geographic frontier is a loss. The exploration of the west stimulated the imagination. The settlement of the west hardened the muscles and strengthened the moral courage of our forebears. The resources of the west made possible the develcpment of independence of thought and action. It is the conviction that we must find some moral equivalent for the old frontier in our new social, intellectual and spiritual life that leads me to consider the frontiers of science.

Frontiers of Science

In science as in American history the conception of the frontier is inseparable from that of the frontiersman. In science as in history the frontiersman creates the frontier.

Men of the old frontier were of the most diverse sort. Many of the men in buckskin and homespun were merely camp-followers of the real frontiersmen of the west. The analogy must not be too closely drawn between the men of the old border and the frontiersmen of science. The frontiersman of science has in common with the true frontiersman of the American wilderness an unconquerable desire to penetrate the unknown, the courage to follow an individual vision and an exultation in doing the things which others know can not be done.

Not all the lines of Kipling's "The Explorer" measure up to the title, but two of the eighteen verses seem to me to describe graphically the scientific frontiersman as well as the frontiersman of the geographic border.

> "There's no sense in going further—
> it's the edge of cultivation,"

So they said, and I believed it—
broke my land and sowed my crop—
Built my barns and strung my fences
in the little border station
Tucked away below the foothills
where the trails run out and stop.

Till a voice, as bad as Conscience,
rang interminable changes
On one everlasting Whisper
day and night repeated—so:
"Something hidden. Go and find it.
Go and look behind the Ranges—
Something lost behind the Ranges.
Lost and waiting for you. Go!"

Not all men trained in the routine of scientific research can be frontiersmen of science, but only those who have the rare capacity to hear the one everlasting whisper, day and night repeated, so:

Something hidden. Go and find it.
Go and look behind the Ranges—
Something lost behind the Ranges.
Lost and waiting for you. Go!

To those who do hear and who are willing to make the necessary sacrifices the possible frontiers are boundless.

It seems to be worth while to classify some of the frontiers as they exist to-day. In a few years, the advances of science may have been such that a new group of frontiers will be open.

The Obvious Frontiers of Science

The most evident frontiers of science are those associated with the frontiers of geographic exploration. When the word "unexplored" occurred frequently on the maps of the world, men of science often experienced the hardships of the wilderness. They were frontiersmen both physically and intellectually.

The Golden Age of Science that produced Darwin and his eminent contemporaries was an age of geographic exploration—an age when frontiersmen began to create frontiers in the forests, deserts and swamps of North and South America and of the Dark Continent. Geography, geology and the natural history of plants, animals and man were their dominant interest, but it is my belief that their discoveries had a profound influence in stimulating research in other branches of science.

I also believe that the stimulus of the scientific exploration of our own western frontier has played a part not fully realized in our own intellectual development. For example, only a century and a quarter ago Lewis and Clark set out on the great expedition which opened vast areas of the west to scientific exploration. More significant than the fact that their letter of authorization was drawn by the president of the United States in person was the interest of the American people in their explorations. A study of the literature of our western exploration of a century ago furnishes indications of a public interest in science the significance of which has, I think, not been fully appreciated.

Lack of time precludes the listing of the naturalists and geologists who with the fur-traders, with Custer or other military leaders, with the wagon road or the railroad exploring parties or alone with their own blankets and rifles braved the hardships of our western frontiers in search of scientific knowledge. Their work was simple, but it was fundamental. The details of their contributions have long been covered with dust, but their interest in research and their accomplishments under difficulties fired the enthusiasm of their contemporaries. They were few in number, but their spirit of adventurous research still lives in men of to-day who could trace their intellectual inheritance to the scientific frontiersmen of the early days.

The incidents of the physical and moral courage of the naturalists of our old frontier would make an inspiring chapter in the history of science. Let one example which illustrates leadership as well as courage suffice. John Wesley Powell knew that the Grand Canyon of the Colorado should be explored. He might have left the task for some man

with two usable arms, since he had only one. But when he had led the main party as far as they could go without entrusting themselves to boats on a voyage through the unknowable perils of the chasm, his men placed strength of moral courage above the strength of physical completeness and every member volunteered to accompany the leader who had sacrificed one arm in the service of his country and was willing to risk his life in the service of science.

With the passing of our geographic frontier, the physical pioneering on our own continent was largely completed. We shall never again have living and working within our own border such an honorable list of naturalists of the blazed trail as that which might be written for the past century.

But what of our responsibility for the wildernesses of South America, the islands of the Pacific and the great scientifically unexplored regions of Asia. In the attack on these obvious frontiers more than exploration is necessary. A group of able men in the museums and herbaria is essential. Notwithstanding our national wealth we are but pitifully equipped in such specialists. Great collections must go to Europe for study, because we have not the trained men. This is a serious state of affairs for American science. The first results of biological exploration become the types or standards to which all later specimens must be directly or indirectly referred. If these remain in America, we have the bases for great developments in the future. If we allow them to go elsewhere, our future students must go to Europe to study what our own explorers have collected. Some of our industries are now suffering because of our lack of foresight in developing our knowledge of the biological resources of little-explored regions. Our prestige in South America and in the Pacific will suffer if we do not recognize our opportunity.

Frontiers of Laboratory Science

But frontiers of science are not necessarily associated with geographic frontiers. Willard Gibbs, moving quietly, unknown and unnoticed, among his academically prominent associates of Yale, was as truly a pioneer as Daniel Boone or Kit Carson.

As the wilderness gave way to the city and as the power of specialized techniques of research became known, it was inevitable that the laboratory should replace the camp. Thus while the scientific frontiers of the geographic border are the more obvious pioneering, it was inevitable that in time the achievements of the pioneers of the laboratory should come to be the more widely recognized.

The building of laboratory walls about the scientist merely widened his scientific frontiers. He refused to look at the walls—he saw only the vision of the wilderness of problems which he might try to solve with new equipment. His prowess has been unbounded.

The astronomer has analyzed the heavenly bodies as well as charted their positions at present and determined their courses for the future. The physicist has enabled us to hear the voices of our friends across a continent and to look at the shattered bones of our bodies through our flesh. On one frontier the chemist has sought and found new elements; on another he has formulated the behavior of ions in solution; on another he has synthesized by tens of thousands compounds which he once supposed could be made only by some mysterious vital force within the bodies of living organisms.

The biologist did not cease to be a frontiersman when he traded in the old rifle or fowling-piece for the new microscope. The description of the anatomy of the tissues was but a prelude to the tracing of their development from the egg and the sperm. Even the egg and the sperm could not be taken as the be-

ginning. Biological frontiersmen were not satisfied until their structures and development were known. In the biological laboratory, physics and chemistry have been combined with delicate manipulative experimentation which has become a part of every field of research on living organisms. The interrelations of hosts and parasites, both plant and animal, have been unraveled, with vast profit to mankind.

To list again the accomplishments of the frontiersmen of the quiet laboratory would be to recount achievements which have become the commonplaces of the history of science. Instead, I would like to formulate some conceptions of the frontiers of science which are not so apparent or familiar.

The Laboratory on the Geographic Frontier

In the development of biological science there is still a great frontier which must be attacked before the physical frontier has disappeared.

Science has lost irreparably because adequate collections of plants and animals were not made before the inroads of civilization deprived us forever of the opportunity. Powell, in founding and carrying the burden of the Bureau of American Ethnology, was as truly a scientific pioneer as when he entrusted himself to the chasm of the Colorado. Notwithstanding his vision we have forever lost the opportunity of obtaining the full details on which an adequate knowledge of the American Indian must depend.

It is too late to repair these losses. It is our duty to see to it that we do not lose the opportunities which are still open to us for work on plants and animals in their natural habitats. Scientific men of our day will not be content with the natural history that satisfied the early pioneers of botany and zoology. They must have the precision of the laboratory. But it is clear that many of the most urgent problems of biology are in the field. The solution is unique and simple. Frontiersmen of our day must take the methods and equipment of the laboratory into the field.

I can write on this subject with conviction based on my own experience. A main personal botanical interest has lain in the investigation of the physicochemical properties of the plant tissue fluids which are of importance in determining the distribution of natural vegetation.

Space will not permit even a superficial review of the results of the series of investigations which have extended from the rain forests and coastal deserts of the Island of Jamaica through the mesophytic, hygrophytic and xerophytic habitats of North America to the Hawaiian rain forests. It is sufficient to say that the light which these studies have thrown upon the intrinsic factors determining the distribution of vegetation has fully justified the cost in funds, time and personal effort.

Out of these pure science researches has grown the conviction that the physicochemical properties of the plant tissue fluids are of fundamental significance in determining the adaptation of agricultural species and varieties for cultivation under varying soil and climatic conditions. I can not give here the scientific results of the years of study devoted to agricultural plants in our western and southwestern deserts. The highest personal results of these months spent with laboratory equipment in barns, garages, rotting boat-houses and in tents in the open air are twofold.

First, they have led to the establishment of my early convictions that the problems of plant geography must ultimately be written in terms of the physical and chemical characteristics of the plant organism as well as in the history and physical factors of the environment, and that these results obtained in the pursuit of pure science may be of human importance when applied to agriculture.

Second, they have driven home to me the conviction that one must seize such opportunities before it is too late. A few days ago I rode swiftly over splendid boulevards through the golf courses and past the great hotels and luxurious mansions of a southern city which has buried and obliterated for all time the swamp and the strand scrub through which I pushed my way with machete and knapsack only a few years ago. My notes contain all that will ever be known concerning certain features of the vegetation.

In scientific candor let us admit that this case is extreme. In equal candor let us recall that all over our national domain changes in natural conditions are swiftly taking place, and let frontiersmen take the methods of the laboratory into the field before it is too late.

The Frontiers of the Interfaces of the Sciences

As Americans we conceive of the frontier as the fringe between the mapped and the unexplored. In science the frontier is not merely the boundary between the known and the unknown in any great and formally recognized branch of research. It may be the interface of two highly developed sciences. Here I am tempted to illustrate by analogy. Oil and water shaken together remain oil and water still. Each has its own chemical composition, and within the three dimensions of space occupied by each substance as such each has its own physical properties. But at the innumerable surfaces where the oil and the water come into contact special physical forces are in operation. Furthermore, if some substances which are soluble in the two liquids—oil and water—be added to their respective solvents before they are shaken together to disperse one liquid as fine droplets throughout the other, these dissolved substances appear to behave in a very orderly way at the frontiers of the respective solvents. Such phenomena are not limited to the surface of contact of the two liquids. They are found to some extent whenever a solution comes in contact with the walls of a beaker, or with the air above. This multitude of problems was scarcely thought of a few years ago. Technically they are known as the problems of the interface. They might as well be called the problems of the frontiers of the solutions.

Now in the development and differentiation of science new fields are apt to be opened up by some imaginative leader—by some frontiersman of science. Others contribute details. A new terminology is developed and the science congresses are like the latter days of the Tower of Babel. The high specialization necessary in any branch of science isolates it for a time from other branches. Intensive development creates frontiers or barriers. This isolation has always been present in science. There was a time when astronomy was largely independent of physics and of chemistry, when chemistry had no bonds with physics and when biology had no place for either physics or chemistry. In our day the great sciences tend to break up into highly specialized fields. Theoretical physics has its own language. Genetics seeks an independent status.

An inevitable result of specialization is that after a time the development of a given branch of science seems to its workers to be at an end. But this is the very moment when the problems of the interface must be attacked. Physics must be brought to the service of astronomy, chemistry and biology. Chemistry must find its way into biology. Morphology must be considered in the light of physiology. The physiologist must draw upon physics and chemistry, and must wake up to the fact that his science is no science at all if structure as well as function is not taken into account.

I like to think of scientific research as a problem in dimensions. Any single

method or any narrow field of specialization may be considered one-dimensional. Thus if two different methods be employed the investigator is working in two dimensions.

One-dimensional research has been so fruitful in the past that we have overglorified the importance of specialization. It often happens that the results of specialized research do not attain their fullest importance until they are considered in connection with the results from a quite different field.

For example, hybridization was developed as an independent field of scientific research. When I was a student, cytology was being hailed as the newest line of specialization—the highest refinement of anatomy or morphology. But cytology might now be a rather obscure phase of biological science were it not for the fact that students of genetics are seeking to find in physical structure some basis for the interpretation of the results of experiments in hybridization. Thus genetics must develop with due regard to the dimensions of two formerly independent fields of specialization.

If three lines of specialization are involved the solution of problems becomes three-dimensional. For example, William Bateson raged when W. F. R. Weldon ventured to calculate probable errors for the sacred results of Gregor Mendel. Now it is only the high and mighty in genetics who can disregard such criticism of the significance of their results. Genetics is developing in three dimensions—experimental hybridization, cytology and mathematical analysis.

Each new field of intensive specialization merely adds one more to the number of dimensions which must be considered by those who are working on the frontiers of the formerly independent branches of science and striving to bring unity out of chaos.

Let us draw another illustration of a somewhat different kind from the science of botany. Suppose that we consider the mapping of the distribution of the vegetation of the earth. We say that the plants are distributed over the surface of the earth. Thus theoretically it would seem quite simple to map the occurrence of species and larger groups in two dimensions of space.

Such a vegetation map is, however, largely meaningless unless we take into account the differences of temperature which are associated with elevation above sea-level and with distance from the equator. This adds another space dimension to our map. Again, the degrees of longitude and latitude and the contour lines of the map of the geographer give no information concerning the physical and chemical properties and water content of the soil. These properties are of fundamental importance in determining plant distribution. Thus the dimensions of water content, physical properties and chemical composition of the soil must be scaled on our map as additional dimensions. Our map has, in short, changed from a distribution in two-dimensional space to a map in many-dimensional space.

But even the foregoing dimensions are not adequate. The earth's crust is not static. It is subject to perpetual change which affects the distribution of plants. Conversely, the vegetation determines in some measure the changes which take place in the physiographic features. The physical and biological systems are not independent but intimately interrelated. Furthermore, living plant species are the present-day descendants of floras of ancient times. The distribution of the present is not independent of that of the past. No map will convey an adequate picture unless all these dimensions of time are represented.

This illustration has been drawn not for the purpose of depicting the complexity of botanical problems but to show the many lines of contact between the various sciences. Geology, meteorology, physics, chemistry and physiol-

ogy all have lines of contact in the adequate mapping of vegetation. Along all these interfaces between botany and the other sciences there is room for pioneer work.

The fruitfulness of research on these frontiers which represent the borderlines of different sciences is perhaps best illustrated by the frontier where biology and mathematics meet. It is but relatively a few years since these sciences were generally supposed to have nothing at all in common. Mathematics had found its place in astronomy, physics and chemistry, and these were known as the exact sciences. Biology, on the other hand, was called a descriptive science.

It is needless to say that the frontiersman who had the courage to assert that biological research must be prosecuted by mathematical methods had to contend against the most determined and bigoted opposition. Support was refused. Publication space was denied. Results were ignored or misrepresented. Mathematical biologists were criticized on the ground that the problems which they considered were not biological problems at all, the critics thereby evidencing their own incapacity to grasp the real possibilities of biological research. As work on the development of mathematical theory adequate for dealing with biological problems has advanced the biological problems themselves have widened.

The accomplishments of mathematics in biology have been so great and so varied that we dare not enter on the task of a review. For nearly thirty years I have not been particularly interested in any one specific biological problem. I have been interested in what I have felt was the more important problem, *i.e.*, the problem of the method of solving biological problems. During this time I have never come into contact with any biological investigation which could not be at least supplemented by mathematical methods. Prophecy is always dangerous, but I would like to be written down as having said that no biological problem of significance will be found in which mathematical methods of description and analysis will not ultimately be applied.

Biometry is entering a far broader field of influence. It early became a factor in psychology. It must ultimately contribute what is quantitative in sociology. Physics is now using the same theories of probability as those which underlay the development of mathematical biology. Pure mathematics is beginning to feel the influence of the mathematics developed for biological application. Finally, the philosophy which underlies the mathematical theory which has been developed for biological research is now beginning to influence our outlook on all scientific research.

Frontiers of the Application of Scientific Research

I have tried to show that the frontiers of science are not limited to the geographically regional, nor yet to the outer fringe of a single highly developed laboratory science. There are new frontiers of research to be created by those who have the fortitude to take the methods of the laboratory into the wilderness. Finally, there are vast frontiers of the highest promise for those who can master the perplexities of the interfaces between our established branches of science, thus making it possible to write our knowledge of the universe in fewer but more comprehensive equations.

But the frontiers of science are not limited to the boundary line between the surveyed and the unblazed in a specific field of research, nor to the undetermined relationships between two or more highly developed fields of research. The frontiersman of science may traverse either of these wildernesses for the exultation of seeing and recording what has not before been seen or of grasping and formulating relationships not heretofore

conceived. On the other hand, he may be fired with the idea that in the last analysis science has a human service to render.

There are frontiers of application of science to human welfare as well as frontiers of research.

It is worth while to consider first the so-called fields of practical application. Economic application would perhaps be a better term, for those things which count for the enlightenment and intellectual inspiration of mankind are quite as practical as those which contribute to physical comfort.

Since it is impossible to list all the frontiers of the application of the results of scientific research, it will be interesting to consider some of the new frontiers of application which have been created by the movement of the vanguard of population across the continent. Such new frontiers have been created by every stage of social development which has followed the penetration of the wilderness.

The pioneer was prodigal in his waste of natural resources. To his view the horizon of natural wealth was boundless. Why should he conserve the forests when no one knew their extent? Why fertilize the acre when a new acre of virgin soil could be cleared to replace the one exhausted of its fertility? Why think of the future of the range when cattle and sheep by the hundreds of thousands pastured at public expense meant private gain?

The need of these resources which we begin to feel to-day will become acute in the future. But the replacement of forests, the restoration of the fertility of the soil, the rehabilitation of our range and the reduction of dangers from floods due to the disturbance of natural conditions are not to be accomplished by the appointment of commissions of politicians with highly paid secretaries and budgets for inspection of the work of similar commissions in other states. They can be accomplished only by the basis of the most diverse kinds of research on as yet practically untouched frontiers of biological science.

In grappling with these problems more than science as we conceive it to-day is required. These are not problems of biology alone—they are problems of the application of the results of biological research under difficult economic and political conditions. It is here that some new type of man must establish his interests on the frontiers of biology and economics.

But new frontiers of the application of the results of biological research are not solely those called into being through the uncurbed exploitation of our natural resources by the vanguard of settlement.

Our growth has been so rapid on the scale of time as conceived by the historian that the blue smoke from the cabin chimney in the clearing had hardly faded away before the black cloud from the smokestack sifted its grime over the cottages of the laborers in the mines and the mills. Centers of population grew apace and solid blocks of grain and orchard were required to load the trains that carried food from areas where it could be grown to the industrial centers where it might be consumed. The old frontiers of human settlement thus vanished, but new frontiers of scientific application sprang into being. The orchards and crops that were free of disease when grown in the isolated patches of the settler became the paradise of fungus and insect when grown in solid blocks of miles. Food deteriorated or perished in transit. Paragraphs would be required to list the specific biological problems which have been created by urban development. Epidemics swept the crowded cities, and means of prevention had to be sought and made effective. Streams were polluted by sewage, endangering the health of those below. Glowing filaments replaced sunlight and the flickering candle, and new problems

of the physics and physiology of vision forced themselves upon the attention of the investigator.

Noble work has been done, but trails have hardly been broken in many of the new frontiers for the application of science created by the needs of new and ever-changing conditions.

Frontiers of Scientific Education

The frontiers of science are not limited to research and to the application of the results of research. There are also frontiers of scientific education. I do not refer to the technique of science teaching, but to the greater problem of making science a more important factor in our future economic, intellectual and social life.

One such frontier is the enlightenment of the public as to the significance of pure and applied science. It is too generally assumed that applied science is of human value, while pure science is of merely academic interest. Those who hold this view are blind to two great principles.

First, science has an intellectual significance in the development of our culture which is independent of its material contribution to our comfort.

Second, the actual relationship between pure and applied science is such that pure science research lays the foundations for application. Scientific men are often urged to prune the many-branched tree of research in order that it may bring forth the fruits of practical accomplishment more abundantly. Those who recommend the pruning-knife should understand that if it is applied to pure science it will be the roots which nourish the whole tree that are lopped off.

Another frontier for those who feel the call of scientific education is that of a serious and sympathetic attack on the old idea that science lacks esthetic value—that science is unimaginative, if not sordid. Science has by virtue of its practical human service taken its place alongside the humanities, but there are still those who feel that it is not one of the humanities. They assert that science must be humanized.

If science were valuable only as it makes two blades of grass to grow where but one grew before, only as it gives us the results of the election before the dawn of the day after the ballots are cast instead of a month later, only as it distributes the latest syncopation from the grill room to drown out meditation by our firesides, I might agree that science has not won its place among the humanities. But it is only the superficial observer who fails to see the beauty in science beneath the mechanism and the detail.

Two familiar cases will serve to illustrate.

I do not know whether the discovery of Neptune has carried with it any practical advantage to mankind, but to me the location of an unknown planet by mathematical reasoning and the experimental verification of the deductions by the telescope is far more dramatic than anything which we know in literature.

It is fortunate for the United States that we have in our own boundaries the richest known supply of helium. It is practically important that the wells be capped and the precious non-explosive gas be conserved. But the importance of the existence of helium in quantities sufficient for aerial navigation dwindles into insignificance in comparison with the intellectual value of the fact that science made it possible to discover helium in the sun before it was found on the earth. That helium could be detected in the sun before it was found on the earth makes us as human beings worthy to look down on the earth as we fly through the clouds.

One may define *humanities* in such a way as to include or to exclude whatever one likes. Those who care to do so may exclude from the humanities the inspiration of the discovery of Neptune, of

helium, of radium, or of the formulation of the idea of the orderly development of the biological universe. Whether science belongs to the humanities or not, the equation for human physical development, human inheritance and human behavior must be written in the terms of quantitative science.

In all these things there is the highest esthetic value—the beauty of magnificent orderliness.

To be sure, many have not the capacity to see the beauty beneath the apparent confusion of detail, but for those who do science can have no benumbing influence on the esthetic faculties.

Darwin's words have been so often quoted that it would be superfluous to repeat them were it not for the fact that I wish to preach a new sermon on the old text. In 1876 he wrote:

> I have said that in one respect my mind has changed during the last twenty or thirty years. Up to the age of thirty, or beyond it, poetry of many kinds . . . gave me great pleasure and even as a schoolboy I took intense delight in Shakespeare, especially in the historical plays. I have also said that formerly pictures gave me considerable, and music very great delight. But now for many years I can not endure to read a line of poetry: I have tried lately to read Shakespeare, and found it so intolerably dull that it nauseated me. I have also almost lost my taste for pictures or music. Music generally sets me thinking too energetically on what I have been at work on, instead of giving me pleasure. I retain some taste for fine scenery, but it does not cause me the exquisite delight which it formerly did. On the other hand, novels which are works of the imagination, though not of a very high order, have been for years a wonderful relief and pleasure to me. . . .
>
> This curious and lamentable loss of the higher aesthetic tastes is all the odder, as books of history, biographies and travels (Independently of any scientific facts which they may contain), and essays on all sorts of subjects interest me as much as they ever did. My mind seems to have become a kind of machine for grinding general laws out of large collections of facts, but why this should have caused the atrophy of that part of the brain alone, on which the higher tastes depend, I can not conceive. A man with a mind more highly organized or better constituted than mine, would not, I suppose, have thus suffered; and if I had to live my life again, I would have made a rule to read some poetry and listen to some music at least once every week; for perhaps the parts of my brain now atrophied would thus have been kept active through use. The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature.

There may be some question as to whether Darwin did not overestimate his loss. Those who knew him doubted whether there had been any real "atrophy of that part of the brain on which the higher tastes depend." Darwin was perhaps as much mistaken here as he was when he thought that his books might last "a few years."

Thoughtless writers do not stop to inquire whether men who spend their years in business or even in pursuit of the fine arts derive as much pleasure from paintings, music and poetry when they are nearly seventy as when they were twenty-five years of age. They merely quote Darwin's words to show the baneful effect of scientific work on the higher esthetic faculties. Admitting for the sake of argument that Darwin's self-appraisal of his loss of interest in music, painting, poetry and natural scenery may have been correct, a quite different explanation appeals to me as being the more sound. To me the explanation seems to be that Darwin's own great philosophical generalizations overshadowed in esthetic magnificence the poetry and the music and the scenery which gave him pleasure in his youth.

And even if Darwin was wholly right in his evaluation of his "loss of the higher aesthetic tastes" was not his loss the world's gain? Hundreds of millions in each generation may seek to preserve the enjoyment of all their faculties. It is only a great intellectual frontiersman who can give the world a great generalization which has influenced all modern thought.

The Sacrifice of the Frontiersman

It would not be right to close this brief survey of the many frontiers of science

which call for men of vision and determination without emphasizing the fact that the frontiersman of science must encounter great personal hardships and bitter personal disappointments. The frontiersman like the prophet may be without honor in his own country or in his own generation. In science as in geographic exploration it sometimes turns out that the Christopher Columbus is in disfavor while the Amerigo Vespucci gives his name to the Great Discovery.

By way of comparison it is desirable to recall the sacrifices which the pioneer of our west made in exploring and opening to trade and settlement that part of our national domain. Since all that can be done is to illustrate, let us take a few lines from the journal of one whom we may designate as "the unknown frontiersman." In 1827 he found at a trading-post those who could give him information concerning his old companions.

> Here I met again some of the companions who came with me in the first instance from the United States. I enquired about others whom I held in kind remembrance. Some had died by lingering diseases and others by the fatal ball and arrow, so that out of 116 men, who came from the United States in 1824, there were not more than sixteen alive. Most of the fallen were as true men, and as brave as ever fired a rifle, and yet in these remote and foreign parts found not even the benefit of a grave, but left their bodies to be torn by the wild beasts or mangled by the Indians.

Later, as he took passage from Vera Cruz, he wrote with simplicity but with unconscious eloquence of his seven years of failure:

> It would be idle for me to attempt to describe the feelings that welled in my heart, as the sails filled to bear me from the shores of a country, where I had seen and suffered so much. My dreams of success in these parts considered most important by my fellow men, were banished forever. After all my endurance of toil, hunger, thirst and imprisonment, after encountering the fiercest wild beasts in these deserts, and fiercer men, after tracing streams before unmeasured and uncharted by any of my race to their source over rugged and pathless mountains, subject to every species of danger, want and misery for seven years, it seemed hard to be indebted to Charity, however kind and considerate it might be, for the means of returning to my native land.

It is not uncommon to find such expressions of disappointment in those who have been frontiersmen in science. Gregor Mendel, after years of painstaking work, would say hopefully or sadly, "Meine Zeit wird bald kommen." But it did not come until long after the candles burned about the bier of the old abbot. I have already quoted Darwin's words, and while I am not at all sure that he was right in his self-judgment, they at least indicate some of the personal sacrifice which he felt he had made when he found that he had so lost the capacity for relaxation that he felt impelled to write, "My mind seems to have become a kind of machine for grinding general laws out of large collections of facts."

It is needless to multiply illustrations. Kipling has, I think, caught and fittingly expressed the sense of disappointment of the old explorer who heard the whisper, "Something lost behind the Ranges. Lost and waiting for you. Go!" After all his sacrifices and hardships he says:

> Well I know who'll take the credit—
> all the clever chaps that followed—
> Came, a dozen men together—
> never knew my desert fears;
> Tracked me by the camps I'd quitted,
> used the water-holes I'd hollowed,
> They'll go back and do the talking.
> *They'll* be called the Pioneers!
>
> They will find my sites of townships—
> not the cities that I set there.
> They will rediscover rivers—
> not my rivers heard at night.
> By my own old marks and bearings
> they will show me how to get there,
> By the lonely cairns I builded
> they will guide my feet aright.

These words ring true for the scientific frontiersman as for the explorer, for the frontiersman of science is an explorer. The frontiersman of science is

in advance of his time. He must first of all contend with those who say:

> "There's no sense in going further—
> it's the edge of cultivation."

He must often go beyond the ranges without support and under opposition. When he does succeed, it will often have been at a cost of effort which will lead him to look back on the deserts he has crossed and to say with Kipling's "Explorer":

> I remember going crazy.
> I remember that I knew it
> When I heard myself hallooing
> to the funny folk I saw,
> Very full of dreams that desert:
> but my two legs took me through it . . .
> And I used to watch 'em moving
> with the toes all black and raw.

And when he has traversed the great region beyond the foothills, he may have been so much in advance of his time that all the water-holes he hollowed, all the lonely cairns he builded will be forgotten by the clever chaps that follow. They'll be called *the Pioneers.*

All these things must be the lot of the real frontiersman of science. But the vast frontiers of science await—frontiers wider and deeper than any conceived by the geographer of the great era of exploration; frontiers on the exploration of which our future economic, intellectual and social development depends.

The Need for Frontiersmen of Science

If I seem extreme in my views, consider what Lord Curzon had to say twenty-two years ago concerning the influence of geographic frontiers on the development of Anglo-Saxon character. Of the evolution of the character of the American people as conditioned by their westward march across the continent he said:

> In no land and upon no people are the evidences more plainly stamped. Not till the mountains were left behind and the American pioneers began to push across the trackless plains, did America cease to be English and become American. In the forests and on the trails of the Frontier, amid the savagery of conflict, the labour of reclamation and the ardours of the chase, the American nation was born. There that wonderful and virile democracy, imbued with the courage and tenacity of its forefathers, but fired with an eager and passionate exaltation, sprang into being. The panorama of characters and incidents, already becoming ancient history, passes in vivid procession before our eyes. First comes the trapper and the fur-trader tracking his way into the Indian hunting-grounds and the virgin sanctuaries of animal life. Then the backwoodsman clears away the forests and plants his log hut in the clearings. There follow him in swift succession the rancher with his live-stock, the miner with his pick, the farmer with plough and seeds, and finally the urban dweller, the manufacturer and the artisan. On the top of the advancing wave floats a scum of rascality that is ultimately deposited in the mining camps of California and the gambling dens of the Pacific Coast. Scenes of violence and carnage, the noise of firearms, and the bleaching bones of men, mark the advance. The voice of the backwoods-preacher sounds through the tumult in accents of mingled ecstasy and rebuke. But from this tempestuous cauldron of human passion and privation, a new character, earnest, restless, exuberant, self-confident, emerged, here an Andrew Jackson, there an Abraham Lincoln, flamed across the stage; and into this noble heritage of achievement and suffering, the entire nation, purified and united in its search for the Frontier, both of its occupation and its manhood, has proudly entered.

Then turning to the other side of the world, where on a widely different arena but amid kindred travail the British Empire may be seen shaping the British character, while the British character is still building the British Empire, he says:

> There, too, on the manifold Frontiers of dominions, now amid the gaunt highlands of the Indian border, or the eternal snows of the Himalayas, now on the parched sands of Persia or Arabia, now in the equatorial swamps and forests of Africa, in an incessant struggle with nature and man, has been found a corresponding discipline for the men of our stock. Outside of the English Universities no school of character exists to compare with the Frontier; and character is there moulded not by attrition with fellow men in the arts or studies of peace, but in the furnace of responsibility and on the anvil of self-reliance. Along many a thousand miles of remote border are to be found our twentieth-

century Marcher Lords. The breath of the Frontier has entered into their nostrils and infused their being. . . . The Frontier officer takes his life in his hands; for there may await him either the knife of the Pathan fanatic, or the more deadly fevers of the African swamp. But the risk is the last thing of which he takes account. He feels that the honour of his country is in his hands. I am one of those who hold that in this large atmosphere, on the outskirts of Empire, where the machine is relatively impotent and the individual is strong, is to be found an ennobling and invigorating stimulus for our youth, saving them alike from the corroding ease and the morbid excitements of Western civilization. To our ancient Universities, revivified and reinspired, I look to play their part in this national service.

Our western frontier has passed into history. With it has gone one of the forces which developed our national character. For it we must find some equivalent. We have not the wide-flung frontiers of the British Empire. We must make ours the responsibility for other frontiers of our own creation. The wilderness of opportunity lies all about us. Geographically, the world is mapped; biologically, it is largely unexplored. The natural history of plants and animals is partly known; the application of methods of precision to these problems is scarcely begun. Individual branches of science are highly developed; the unification of the sciences is a vision still to be realized. The application of the results of pure science research has transformed our industrial life; more extensive results still await application. Biological resources have been exploited in the past; they must be conserved, developed or replaced through scientific research in the future. Science has contributed enormously to our physical comfort; the scientific method of thought still fails to influence the personal lives of the mass of our citizens. We await only frontiersmen to create the new frontiers beyond the foothills where the trails run out and stop. I venture to think that in the manifold frontiers of science we shall find one of the means of meeting the moral needs of our time.

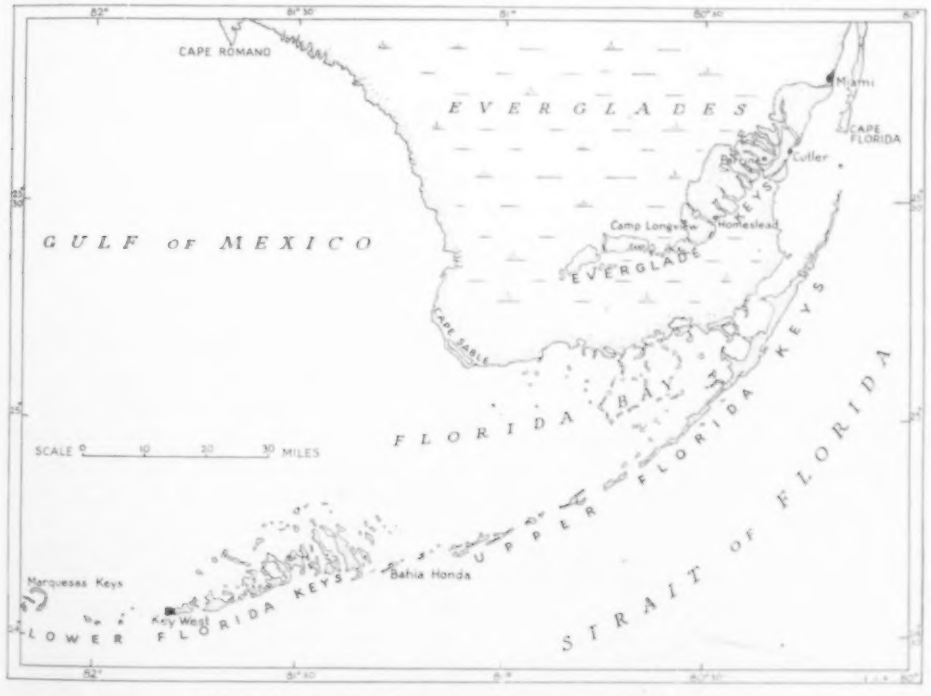
VEGETATION AND EROSION ON THE EVERGLADE KEYS

By Dr. JOHN K. SMALL
NEW YORK BOTANICAL GARDEN

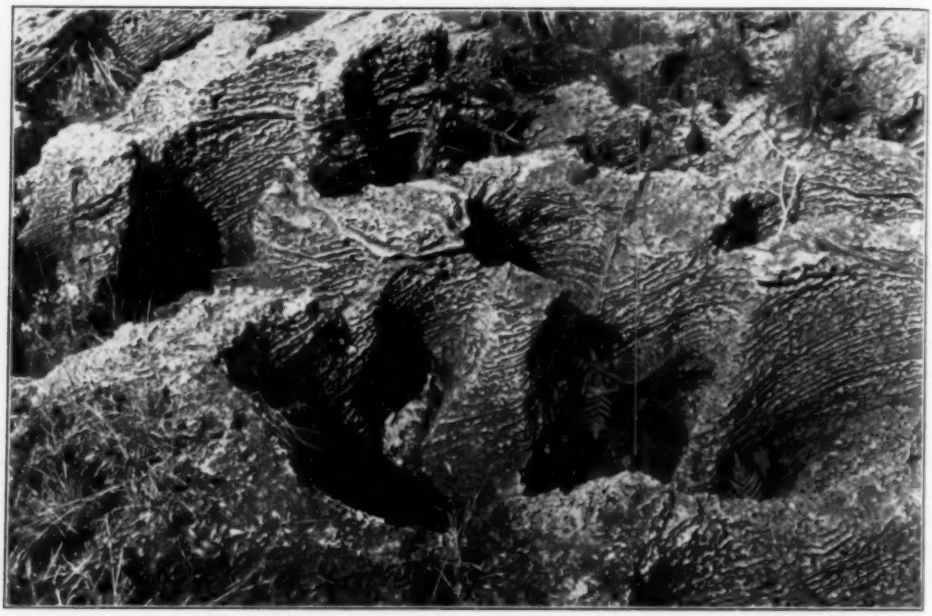
THE traveler in southern Florida meets two strikingly different associations of trees and shrubs. They are the pinewoods and the hammocks.

The pinewoods or pinelands of Florida are nearly level areas of greater or less extent; the high pinelands are dry and often somewhat rolling; the low pinelands where the water-table is always near the surface are often called "flatwoods" because of the flatness of the land. They are composed, according to locality or region, of one or another of the several long-leaf pines. The undergrowth consists of saw-palmetto, shrubs (particularly scrub-oaks), and annual and perennial herbs. They are often fire-swept, and consequently the soil, sand or rock is nearly or quite devoid of humus. As a result of frequent fires and an impoverished soil there is no tall growth aside from the pine-trees, which do not require humus as do broad-leaved trees.

The hammock—the word probably of Indian origin—is a dense growth of mostly broad-leaved trees and shrubs. Sometimes hammock growth occupies a whole circumscribed portion of a geologic formation; at other times it occurs



MAP OF THE SOUTHERN END OF FLORIDA
SHOWING THE LOCATION OF THE EVERGLADE KEYS AND THE FLORIDA KEYS.



EROSION PRODUCED BY MAINLY HUMUS-ACCUMULATION

ON AN ORIGINALLY FLAT SURFACE IN THE SNAPPER CREEK HAMMOCK SOUTH OF MIAMI. THE UNEVEN COMPOSITION OF THE OOLITIC ROCK IS INDICATED BY THE EROSION CAVITIES. THESE CAVITIES IN THE PRESENT-DAY HAMMOCKS ARE MOSTLY EMPTY OR ONLY PARTLY FILLED WITH LIGHT HUMUS WHICH HELPS TO CONTINUE THE EROSION WHICH IS NOW ACTIVE JUST AS IT WAS FORMERLY. THE STRATIFIED CHARACTER OF THE LIMESTONE MAY BE SEEN ON THE SIDES OF THE CAVITIES WHERE THE NUMEROUS STRATA ARE QUITE EVIDENT.

as an island, so to speak, surrounded by pinewoods or prairie. It was formerly confused with the word hummock, a topographic term. Hammocks occur only in regions protected from fire, or in fire-ravaged regions they represent areas that fire has not yet run through. The hammock can not be correlated with altitude or with subsoil, for beneath the humus, resulting from the decaying vegetable matter, may be sand, clay, marl or rock. The use of the word is confined mostly to Florida and adjacent states.

The pinelands predominate in extent of area. The hammocks are infrequent, usually relatively small, and isolated. They are, however, really very significant.

The casual observer sees these associations merely as so many woody plants of diverse characters growing in groups, noticing, of course, the great discrepancy in the relative extent of area of the two main associations. The more careful observer, however, realizing that there must be some reason for the present disproportion of the two associations, seeks to learn if the hammocks have been and are retreating or advancing, and the reasons therefor. The hammock is spontaneously used as the gauge, perhaps because it is the exception. Yet it is also the more prominent feature because of the monotonous landscape furnished by the endless pinewoods. Even the more careful observer, however, may not appreciate the situation fully or grasp the fundamental problems.

What was the tree-covering of that area, now known as the Everglade Keys, at, say, the time man appeared on the

scene? Was it all hammock or was it all pinewoods? Was its arboreous vegetation composed of some ratio of both associations as we find them to-day? In considering this question one must begin with the period following that in which the materials of the Miami oolite had been laid down and cemented together on the bottom of the sea, that is to say, when the islands thus resulting were clothed with their earliest arboreous vegetation. Are the elements of the present herbaceous and woody plant-covering mainly the direct or indirect descendants of this early vegetation?

Of course, the land may have been, then or later, much more elevated above the sea than at the present time. However, such elevation would apparently be of minor importance in the present connection. The general surface of our region could not, in any case, have been much lower, once the forests were established, else the islands would have been submerged by the surrounding salt-water and original vegetation "drowned out." On the other hand, it is certain that the present kind of plant-covering could have existed on a much more elevated plateau, even up to an altitude as high as the available evidence indicates the region once actually attained. Moreover, if, after the existing vegetation had developed, much depression occurred, one would expect to find coastwise or shore plants now isolated in at least some places in the interior where but little elevation now obtains; but such are lacking. It is true that the red-mangrove (*Rhizophora*) and the buttonwood (*Conocarpus*) do grow at a few places rather remote from the present shore-line of the peninsula, but their presence wherever they have been found is easily accounted for otherwise. When and how much the area under consideration was elevated, however, or how much it was depressed, does not, as we have already intimated, complicate the present problem.

Three geologic areas are here involved. These also circumscribe three phytogeographic areas. They are:

I. The upper Florida Keys which are composed of coral-rock and extend from Soldier Key for a distance of about one hundred and twenty miles to the West Summerland or Spanish Harbor Keys. The islands are for the most part greatly elongated and with the long axis in a curve following the general trend of the adjacent mainland. The limestone, mainly an unchanged fossil coral, is named for the largest island, the Key Largo limestone.

II. The lower Florida Keys are a natural group of islands extending from No Name Key and Little Pine Key in a westerly direction for a distance of about forty miles to Key West. The islands of this group are composed of oolitic limestone, and although irregular in shape, the long axis is nearly north and south, thus also differing from those of the previous group. The limestone is technically known as Key West limestone, named for the best-known island of the group.

III. The Everglade Keys or the Miami Limestone Region, an area of exposed oolitic limestone, is the region with which we are directly concerned. It consists of a chain of islands enclosed by the southern portion of the Everglades, except where some of the islands come in contact with the upper part of Bay Biscayne. The chain stretches in crescent form from somewhat north of the Miami River southward towards Cape Sable for a distance of about fifty-five miles. The islands in ancient times apparently formed a part of the Antilles. This was at a time when the subterranean mountain whose summit makes the present peninsula of Florida was less elevated and the islands themselves less eroded. The native vegetation of the islands is essentially of a tropical character, with strong relationships to the flora of Cuba and of the Bahamas. As

EROSION PRODUCED BY HUMUS-ACCUMULATION

ON AN ORIGINALLY FLAT SURFACE NOW IN THE PINELANDS IN THE NORTHERN PART OF MIAMI. THERE TOO (COMPARE FIRST FIGURE) THE UNEVEN COMPOSITION OF THE LIMESTONE IS SHOWN BY THE EROSION CAVITIES. THE RESULTS OF EROSION IN THE PINELANDS IS QUITE SIMILAR TO THAT IN THE HAMMOCKS, AS SEEN IN THE FIRST FIGURE, FOR THE EROSION TOOK PLACE WHEN THE PRESENT PINELANDS WERE HAMMOCK. AFTER THE HAMMOCK WAS DESTROYED THE PINE-TREES REPLACED THE BROAD-LEAVED TREES AND THE CAVITIES WERE GRADUALLY FILLED WITH PIECES OF ROCK AND SAND. THEY ARE THUS USUALLY UNNOTICED UNLESS THE DÉBRIS HAS BEEN REMOVED AS IN THE CASE OF THIS FIGURE. THERE THE STRATIFIED CHARACTER OF THE LIMESTONE IS EVIDENT BY THE NUMEROUS LAYERS.

far as the native flora is concerned the Everglade Keys represent a small tropical area isolated on the mainland of the United States. The Everglades are wet prairie covered with saw-grass (*Mariscus jamaicensis*) and devoid of trees, except where hummocks of soil or rock project high enough above the flood-level to permit trees to exist and thus support hammock or pineland.

The islands are made up of an oolitic limestone called the Miami oolite. This formation extends northward—about fifty miles north of the Miami River—as far as the Palm Beach limestone, but for this distance it is mostly covered with a layer of siliceous sand and humus. On the east the limestone runs out into the Atlantic Ocean as far as the Gulf Stream; on the west it dips under the Everglades, while on the south and southwest it joins with the Lossman's River limestone. The Everglade Keys represent the more elevated portions of this oolite. They are, however, but a fraction of this limestone formation. The keys vary greatly in size, from a small plot to one many square miles in extent. Their latest aerial existence dates from later Pleistocene or early post-Pleistocene times. The formation is probably much older than the Key Largo limestone. It gives evidence of more movement, up and down, than does the latter.

The average elevation of the Everglade

Keys is only a few feet, but it is sufficient to enable the islands to support an almost entirely different flora from that of the contiguous territory. Whatever elevations or depressions took place during Pleistocene or post-Pleistocene times, moreover, the minimum elevation here also was apparently sufficient—in some areas, at least—to maintain a continuous plant-covering.

The Everglade Keys, as they exist to-day, are slightly higher than their environs, either land or water. They have been isolated for a long period of time, during which their general height or that of the aerial parts has been much reduced. Their floristics are unique in Florida. If the southern end of the peninsula was higher at one time, and the present characteristic flora of the Everglade Keys did occupy a greater area than it does now, the eventual subsidence obliterated all traces of the flora beyond its present sharply defined limits.

Consider, first, the most recent rock formation in Florida of an extensive and definite area. This is the Key Largo limestone—a formation built up on a foundation on the Florida reef or Continental Shelf. The Key Largo limestone comprises the upper Florida Keys extending from Soldier Key to Bahia Honda Key and a little further westward along the fronts of several of the oolitic limestone keys. Nowhere else is the Key Largo limestone present. It was evidently the last definite and isolated geological formation in Florida to have been forested. Likewise, it was, perhaps, the latest to be inhabited by primitive man.

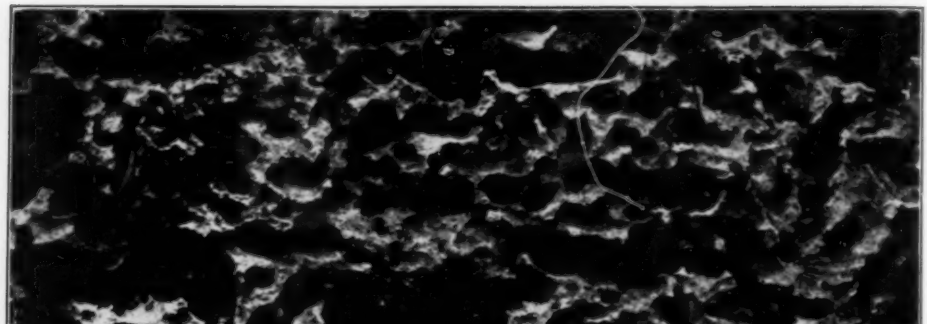
Its vegetation is related to that of the younger West Indian islands, whence its ancestors may have been derived. Until the present century, apparently, it had been little changed either by nature or by man. The flora is a simple one, and shows much less variety and less influence from the advent of other floras than its neighboring plant-regions, *viz.*, the lower Florida Keys and the Everglade Keys.

Without exception the islands of the upper Florida Keys are clothed with broad-leaved plants or hammock. Not a native pine-tree grows there. The vegetation has apparently been undisturbed on most of the islands except for modern cultivation and residential purposes and more recent railroad construction and automobile-road building.

Natural forest fires in prehistoric times were apparently very rare. The rapid reforesting and long spells between fires coupled with the somewhat isolated position of the islands have prevented a different character of tree-association from gaining foothold. Nor have recent fires, incident to settling and cultivation, had time to change the woody flora perceptibly, except to deprive it of primeval stateliness.

Even if the upper keys were of relatively recent origin, they would probably have been settled and utilized by some of the aborigines had they possessed an abundance of game and desirable food-plants or areas inviting cultivation. Then their vegetation to-day would have told a different story. As it was, when the white man discovered them these islands were essentially in their primeval condition.

That the flora of the Everglade Keys and the upper Florida Keys had the same origin, or that that of the former was derived, in part at least, from the other, is clear, because the hammock flora of the two regions, particularly the woody elements (the herbaceous elements in the hammocks are rather insignificant), is almost identical. The proportions with regard to area, however, are vastly different. As already stated, the upper Florida Keys support unbroken hammock. The greater portion of the area of the Everglade Keys, on the other hand, is clothed with pine-



EROSION PRODUCED BY ATMOSPHERIC ACTION

AND THE GROWTH OF VEGETATION. THE PICTURE REPRESENTS THE RESULT OF WEATHERING ON A SURFACE, PERPENDICULAR OR HORIZONTAL, OF A MASS OF NON-STRATIFIED OOLITIC LIMESTONE. IN THIS CASE THE OVAL WIND-WORN PARTICLES OF CALCIUM CARBONATE HAVE BEEN CEMENTED TOGETHER INTO AN AMORPHOUS MASS, WHICH OCCASIONALLY CONTAINS FRAGMENTS OF CORALS, PIECES OF SHELLS AND OTHER DÉBRIS. THE EROSION BRINGS OUT THE EXTREME LACK OF UNIFORMITY OF THE DEPOSITED MATERIAL.

woods, and hammock growth is now relatively insignificant in area.

In comparing the vegetation of the two areas under consideration, the question naturally arises as to whether or not the Everglade Keys were once entirely clothed with hammock, as the upper Florida Keys are now. If so, what caused the retreat of the hammocks and the advent of the pinewoods? When and whence did the pine-trees come?

There seems to be little doubt that the Everglade Keys were originally hammock-clad. The circumstantial evidence to support this theory is the present practically undisturbed primeval vegetation of the neighboring and younger geological formation, the upper Florida Keys. The more direct evidence in support of this theory is the type of surface erosion of the rock all over the Everglade Keys. This theory does not apparently appeal to the average superficial observer, for it will appear to him that the erosion in the hammock is quite different from that in the pinewoods.

Let us consider this matter of erosion. In the undisturbed hammocks, as we find them now, is a rock floor covered with loose humus. The carbonic acid and the humus colloids from this decaying vegetable matter which has accumulated for ages, plus rain and capillary moisture and general humidity, have gradually eaten away the softer portions of the limestone. The resulting condition is a copiously honeycombed hammock floor, the cavities varying from the size of a thimble to that of a small house, the depth of the larger holes depending upon the elevation of the hammock floor above the normal water-table. The same condition prevails in the pinewoods. In rare instances is the condition visible, except where the surface débris has been in some way removed, but it does exist everywhere.

In the Miami oolite some parts or areas were composed of nearly pure lime (calcium carbonate). Other areas consisted of a mixture of lime and siliceous sand, and of other matter that was blown or washed in while the limestone formation was being built up. Apparently the major portion of the limestone of the Everglade islands comprises such a mixture. That most of the rock of the pinelands has a large percentage of sand in its make-up has been determined both by analysis and by observation. The disintegration of the limestone is brought about largely through atmospheric or other superficial agencies. First, by the slow but continuous working of the elements; second, by the more rapid action of fire.

Specimens of quicklime made from the oolite gathered in different areas of the Everglade Keys will give two main results upon slaking after a fire. In the one case, but little residue is left; in the other, more or less sand results. In the pinewoods themselves, after a forest fire, one may find quantities of quicklime, particularly where logs or stumps have been burned causing great heat for a protracted time. Observations on these specimens of quicklime after a rain will show that either the slaked lime leaves behind scarcely any residue or that a quantity of often red sand has been left behind. This red sand mixed with a kind of clay has accumulated in the erosion holes on one of the Everglade Keys to such an extent that the region has been designated "the Redlands district," whence Redlands Post Office, Redlands School, and the "Redlands County" hoped for by some.

But here is the point: If one removes the loose material from the rock floor almost anywhere in the pinewoods, he will disclose a system of erosion holes, or, in other words, a honeycombed surface quite similar to that he finds in the hammocks. In the hammocks the smaller holes are largely filled with loose humus;

EROSION PRODUCED BY WATER

PERCOLATING ALONG THE LESS RESISTANT STRATA. A SECTION OF LIMESTONE FROM ABOUT TEN FEET BELOW THE SURFACE IN THE PINELANDS IN THE NORTHERN PART OF MIAMI AT A POINT ABOUT THREE MILES FROM THE EVERGLADES AND ONE MILE FROM THE SHORE OF BAY BISCAYNE. WHEN THE ARTIFICIAL SECTION WAS MADE, WATER WAS FLOWING RAPIDLY THROUGH THE HORIZONTAL CAVITIES MADE BY THE LEACHING OUT OF THE SOFTER LAYERS OF THE STRATIFIED DEPOSIT OF LIMESTONE. THIS ILLUSTRATES ONE OF THE SUBTERRANEAN OUTLETS OF THE WATERS OF THE EVERGLADES.

EROSION PRODUCED BY ATMOSPHERIC ACTION AND VEGETATION

THE PERPENDICULAR FACE OF A FAULT ALONG BAY BISCAYNE, SHOWING TWO KINDS OF ROCK STRUCTURE: BELOW, WELL-STRATIFIED; ABOVE, NON-STRATIFIED. IN ADDITION, THERE IS A STRIKING UNCONFORMITY WITHIN THE STRATIFIED ROCK. THE DIFFERENCE IN STRUCTURE BETWEEN THE TWO TYPES OF ROCK IS EMPHASIZED BY THE EROSION WHICH HAS TAKEN PLACE.

in the pinewoods the holes are filled with sand and other slowly soluble matter that has come out of a less pure limestone. Furthermore, the rock floor under the sediment in Bay Biscayne shows the same characteristic erosion. This condition is an indication that the land there was, at a former period, more elevated. However, there is a certain difference evident. The surface leaching in the pinelands and under Bay Biscayne was long ago much retarded or essentially stopped, while in the hammock areas it continued. Hence, we find larger erosion holes in the hammocks than elsewhere. A difference in the quantity of erosion is quite noticeable in high hammocks and low hammocks. In the former, where water does not stand, the process of erosion is slower and we find small erosion holes, wells and pits; in the low hammocks when water stands part of the year we find benches, tables, pulpits and urn-like structures. Therefore, the surface erosion of the limestone floor, whether in hammock, in pinewoods or under Bay Biscayne as we find it today, is practically identical.

Reverting now from natural forces, so to speak, and considering those brought to bear by man, generally stated, these forces appeared after geologic disturbances had sufficiently subsided, and favorable meteoric conditions had permitted the land to be forested with the primeval hammock. If the human re-

mains found during the past several years at Vero be authentic, man inhabited the Florida peninsula during the Pleistocene. He appeared, in fact, while decided geologic changes were still in progress. But even then vegetation had doubtless become well fixed on the land, and the wilderness as well as the sea abounded in animal life. There is plenty of circumstantial evidence of this, especially in the coastal regions of the peninsula. The aborigines of Florida and the Caribs of the West Indies doubtless were acquainted with the Florida Keys as well. On the lower Florida Keys, where game also abounded, man left his record. But, as mentioned above, the upper Florida Keys did not offer a hunting-ground for the red man or much vegetation in the way of subsistence, so he passed them by—and their hammocks still remain to show his little interest in those islands.[1]

In its primitive condition, the coastal regions of the peninsula with their lagoons abounding in mollusks and their hammocks copiously stocked with birds and mammals and useful plants, particularly the coontie (*Zamia*), furnished primitive man with all the food he could desire. Then, too, the more tempered climate of the region doubtless attracted him toward the southern end of the peninsula.

A portion of the Everglade Keys—now the Deering hammock at Cutler—has from early historic times been designated on various maps as the Indian hunting-grounds. Perhaps this designation should more properly be assigned to the whole limestone region. At any rate, the whole region, and the Big Cypress Swamp to the westward, was the last stand of the game of the state. Only the recent advent of the white man has caused this part of the state to lose its right to the title of "hunting-grounds."

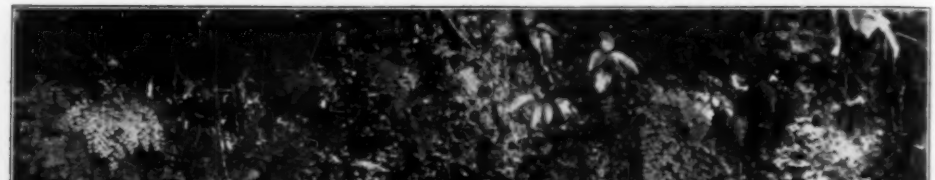
In any case, when the aborigines first occupied the Everglade Keys, they doubtless found them clothed with hammock. Through the mode of life followed by these first inhabitants forest fires were started and were uncontrolled. Later, without doubt, the aborigines purposely set fire to the hammocks in order to drive the game into the open places, thus facilitating their primitive means of hunting game. Fire, in fact, has remained an important and regrettable adjunct of the chase in Florida ever since. The savage white man may sometimes be seen practising it to-day.

Thus large areas of hammock were destroyed. Each fire, we are safe in assuming, pushed the hammock farther back, just as it continues to do to-day. The first fire would destroy most of the humus on the ground, and succeeding fires would make the work of devastation complete.

Moreover, the honeycombed rock, being already burned and weakened by the fire, was exposed to the elements. The limestone that was thoroughly burned was slaked with the first rain. Then the siliceous sand, the unslaked fragments of limestone and other firm materials would fall out. Thus by degrees the honeycombed flood of the one-time hammock lost its character by the breaking down of the edges of the erosion holes and the filling up of the cavities. The process continued until to-day few would suspect that the floor of the pinewoods is to a great extent quite similar to that of the hammocks—often, indeed, it was originally the floor of a hammock—only that its characteristic erosion is hidden from view by the accumulation of débris resulting largely from the effects of repeated fires through a long period of time

The aborigines naturally started fires at different points. One fire after another not only pushed the edge of the

[1] As far as we know, the only evidences of aboriginal occupation on the upper keys are two small Indian mounds near the middle of Key Largo.



EROSION PRODUCED BY ATMOSPHERIC ACTION

COMBINED WITH THE GROWTH OF FERNS AND OTHER PLANTS. THE PERPENDICULAR SIDE OF AN EROSION HOLE IN A HAMMOCK IN THE "HOMESTEAD" DISTRICT. THE EROSION HOLE REPRESENTS A ONE TIME SOFTER LARGE MASS OF LIMESTONE SURROUNDED BY A HARDER MASS WHICH NOW FORMS THE WALLS. HERE THE STRATIFIED PHASE LIES ABOVE THE NON-STRATIFIED ONE (THE REVERSE OF THE NEXT PRECEDING FIGURE) AS BROUGHT BY THE RESULTS OF THE EROSION. THE STRATIFIED ROCK, BOTH BY ITS GROSS AND MINUTE STRUCTURE, YIELDS THE BETTER FOOTHOLD FOR THE GROWTH OF FERNS.

hammock back, but, burning unevenly, a fire or a series of fires finally isolated parts of the hammock growth. Often such isolated bits of hammock persisted. In other words, the condition existing on the Everglade Keys to-day then had its beginning. The fires continued, and in place of a dense broad-leaved forest like that on the upper Florida Keys, clothing the islands, the country became open and often the land was bare. The remaining hammocks naturally tended to reforest the regions, just as they are doing to-day, but the lack of humus would cause a stunted growth and the next fire quickly would obliterate what had been accomplished in the way of reforesting.

But there had been developed plants that were fire-proof, so to speak, just for such regions. The seeds of the Caribbean-pine (*Pinus caribaea*), made to be transported by the wind, blew in from the nearest West Indies and sprouted. The first generation of a single locality may have survived and its descendants spread, or the pine may have started in different places. At any rate, the seedling pine-trees after several years of uninterrupted growth will survive fire, and when a little older they are normally perfectly fire-proof. Thus the pinewoods were developed and have spread as the hammock retreated.

Other plants resistant to fire appeared. Two kinds are particularly abundant and conspicuous in the flora of the pinelands to-day. The coontie (*Zamia*), a cycad, as represented by several species, is exceedingly plentiful. Its stem, a large storage organ, is subterranean and thus safe from fire. *Zamia* is an interesting plant, viewed from any angle.

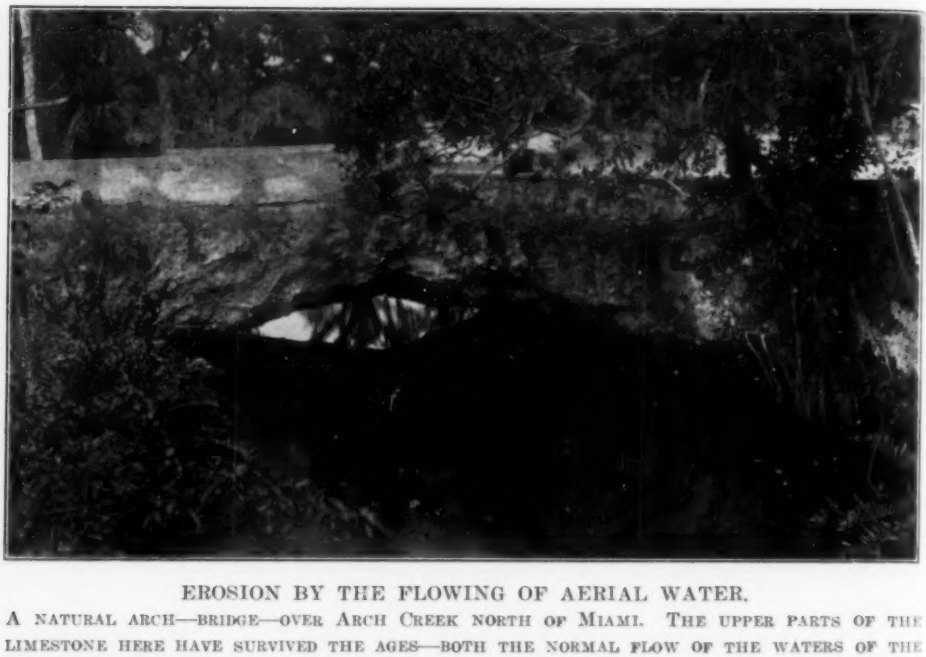
There is a kind of coontie (*Zamia media*) native in and confined to the hammocks in Florida. It occurs in the hammocks of the Everglade Keys, but it is not plentiful—at least not at the present time. It is one of the few hammock plants with a subterranean storage organ. This makes the plants not only safe from permanent injury, but also prevents the species from being exterminated.

When the hammock areas were ravaged by fire and the plant-association later entirely changed in character, this species may have survived and adapted itself to a wholly new environment, and under the new environment developed into another species, ages later, namely, *Zamia integrifolia*. If this species thus survived, it of necessity adapted itself to an open and exposed environment instead of one of shade and protection; it has changed so far as to thrive on fire! The healthier and more robust plants are those that occupy areas that are periodically fire-swept.

The hammock coontie and the pineland coontie are closely related but distinct. Furthermore, neither shows much variation from a set standard. The characters are constant. The species may be separated not only by characters of the inflorescence, but more readily by character of the leaves—differences evidently brought about directly by the different environments.

DIFFERENTIAL EROSION

IN A LOW AREA IN THE DEERING HAMMOCK, CUTLER. AT A REMOTE TIME THE SOFT ROCK HERE WAS GREATLY IN EXCESS OF THE HARD. THE HARDER ROCK IS NOW REPRESENTED ONLY BY THE OBCONIC CORE. THE TOP OF THE CORE WAS ONCE THE LEVEL OF THE HAMMOCK FLOOR. IN THIS AREA THE STRATUM CONCERNED IS ALL UNSTRATIFIED. NUMEROUS ROCK-VASES, URNS, PULPITS, TABLES, SHELVING, PEDESTALS, CANYONS, CAVES, TUNNELS AND NATURAL BRIDGES OF THIS ORIGIN OCCUR IN THIS AND SIMILAR LOW HAMMOCKS, THE SURFACES SHOWING THIS HIGHLY CHARACTERISTIC ROCK HONEYCOMB OR "FILIGREE-WORK."



EROSION BY THE FLOWING OF AERIAL WATER.

A NATURAL ARCH—BRIDGE—OVER ARCH CREEK NORTH OF MIAMI. THE UPPER PARTS OF THE LIMESTONE HERE HAVE SURVIVED THE AGES—BOTH THE NORMAL FLOW OF THE WATERS OF THE STREAM AND THE PERIODIC FLOOD WATERS—WHILE THE LESS RESISTANT MATERIAL BENEATH HAS BEEN ERODED AWAY. THIS ARCH HAS CARRIED THE COUNTY ROAD, NOW A STATE ROAD, SINCE THE COUNTRY WAS SETTLED BY THE WHITE MAN. IT WAS ALSO USED BY THE ABORIGINAL RED MAN, FOR THERE ARE EVIDENCES OF MUCH ABORIGINAL ACTIVITY THEREABOUTS, IN THE WAY OF KITCHEN-MIDDENS, VILLAGE SITES AND BURIAL-MOUNDS. THE CONCRETE WALLS ON EITHER SIDE OF THE ARCH WERE ADDED IN RECENT YEARS.

The primitive species (*Zamia media*), being a shade-loving plant, has soft tissues, few leaves and large leaflets. On account of its subterranean stem it survived the fire-wrecked hammock-association, but its form and quantity of leafage were not adapted to its new environment. In the pinewoods the plant had about the same moisture supply—capillary water—as it did in the hammock, but in addition it had copious and direct sunlight. So, in order to continue its main function—aside from reproduction—the manufacture and storage of starch, the foliage was readjusted. The leaves were increased in number; the leaflets were divided up with the result of more leaflets with fewer veins each, and the tissues became firmer. And we find a more robust and much more prolific plant and a greater starch-storer than the ancestral species.[2]

The hammock coontie does not grow in commercial quantities, but the natural supply of the pineland coontie has been drawn on both recklessly and indiscriminately for several decades for the manufacture of starch in commercial quantities.

The other low plant particularly prominent in the landscape of the pinewoods is the saw-palmetto (*Serenoa repens*). When and how it originated and whence it came we do not know. However, it is now a typical pineland species, and like the coontie it thrives

[2] The writer has plantations of the two species of *Zamia* in reversed habitats, *i.e.*, the hammock coontie has been planted in the pinewoods and the pineland coontie in the hammocks. The results will be watched with much interest.

on fire. It, too, has a function aside from reproduction in the storage of tannic acid in its stems.

The trunks are typically closely prostrate. When fire-swept the plants show only blackened trunks resembling some large reptilian monsters, with the charred stubs of petioles where the crown once stood. After a short period of rest, however, the bud breaks forth with renewed vigor, develops a fresh crown of leaves and inflorescence and soon all is ready for the next fire. So the process continues.[3]

The saw-palmetto is not now a humus-loving plant, although it may formerly have been one. However, it often does grow luxuriantly around the edges of hammocks where some humus mixed with sand seems to stimulate its growth. Many of the so-called homestead hammocks, southwest of Miami, are encompassed with an almost impenetrable girdle of the saw-palmetto. This girdle plays two important rôles, opposites, but each tending to keep the hammock in *status quo*. First, it confines the hammock. Being so dense it prevents the encompassed shrubs and trees from pushing out into the pinewoods. The shade resulting from the numerous broad leaves of the palmetto does not allow the seedlings of the hammock plants to develop, and in addition, the hammock growth adjacent to the palmettos is usually relatively weak and it often keeps at a distance.

Second, the palmetto girdle acts as a fire-break. When the fire in the pinewoods meets the palm cordon, it spends itself, and seldom, unless the natural growth is weak or has been interrupted or otherwise destroyed, eats its way into the hammock. If, however, the fire does break through and burns part of the hammock vegetation and humus, succeeding fires will probably continue the destruction by burning away weak and tinder-like vegetation that may have replaced that formerly burned. Then the pine-trees will spring up, and that much more pineland is added to the region.

Incidentally, the tangled mass of prostrate, floundering and interlaced saw-palmetto trunks furnishes a favorite lair of the diamond-back rattlesnake which can thus prey either on the animals of the hammock or on those of the pinewoods, according to his particular desire or luck.

Thus the hammocks of the Everglade Keys have been crowded back and gradually reduced in size, and then confined. Their flora is not extensive. It comprises mostly woody plants, almost without exception tropical types. There are few herbaceous plants—mostly vines that can climb in the trees and thus get sunlight, smaller plants that can live in humus, epiphytic ferns, bromeliads and orchids and a variety of lower flowerless plants. The herbaceous elements are mostly shade-loving kinds, nearly all of which perish with the first fire. Their whole vegetable make-up is typically that of insular tropical America.

The pinelands, on the other hand, as they gradually increased in size, received

[3] There are many interesting features connected with the "fire-proof" plants. The general results of fire on vegetation are destructive. However, the results are sometimes not wholly negative. For example, the stem of *Zamia* is normally simple and with a single terminal bud. In the pinelands the irritating effects of repeated fires cause a stem to produce additional buds which represent branches. Plants with as many as twelve buds or branches may be found. Thus the yield of foliage and fruit of a plant may be increased twelvefold. Likewise, the saw-palmetto, as in the case of most palms normally, has but a terminal bud. Through repeated irritations by fire an old prostrate stem—trunk—will often send out numerous branches from the spent leaf-axils. Thus, again, the foliage and fruit yield may be materially increased. Even the erect silver-palm may sometimes be found with numerous lateral branches as a result of the irritating effect of fire.

GROTESQUE EROSION

IN A HAMMOCK NEAR MIAMI. HERE THE ONE-TIME GROUND LEVEL OR HAMMOCK FLOOR AND THE ONE OR TWO FEET OF UNDERLYING ROCK HAVE MOSTLY DISAPPEARED. THIS TABLE OF PARTICULARLY HARD PORTION OF THE ROCK, ALTHOUGH OF RATHER EVEN HARDNESS ON TOP, HAD SOFTER PARTS BENEATH AS IS SHOWN BY THE NATURAL-BRIDGE OR TUNNEL MANNER OF EROSION. THE ORIGINAL DEPOSIT HERE WAS UNSTRATIFIED AND LIKE MOST OF THE LIMESTONE OF THE EVERGLADE KEYS THE MATERIAL WAS OF EOLIAN ORIGIN.

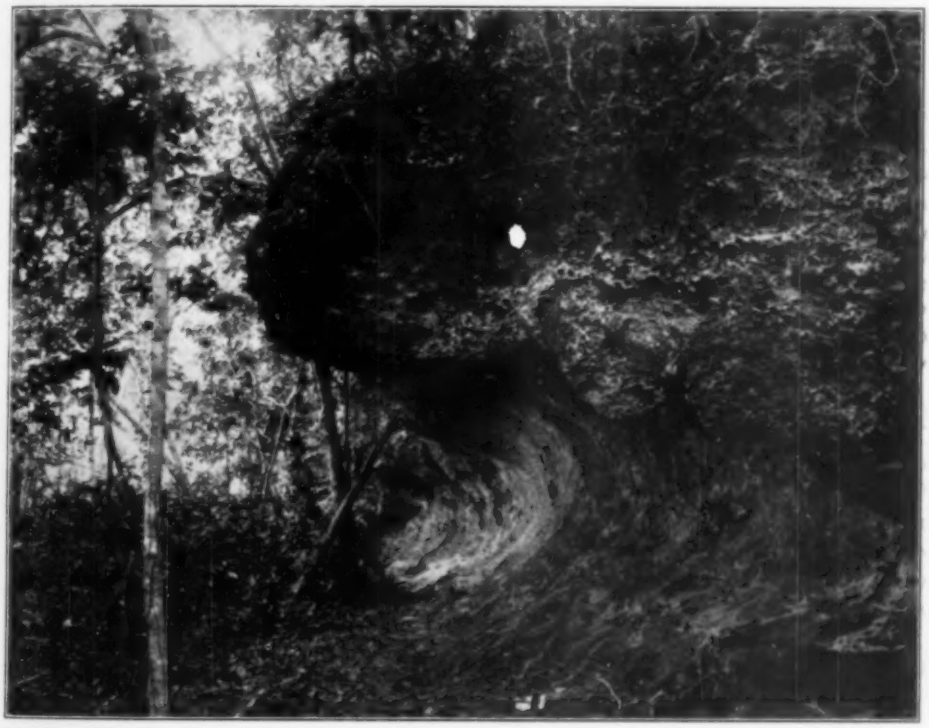
exotic elements into their flora, as well as developing endemic forms. In addition, they have retained many of the hammock plants, but these only in dwarfed, stunted and deformed conditions. Elements of the pineland flora have been derived from the West Indies on the south and from continental North America on the north. Herbaceous plants, not humus-lovers as in the hammock, are abundant. There are annuals that maintain themselves in spite of the frequent fires by dropping their seeds in the sand and in the rock cavities. There are perennials that resist the fire by large woody roots and rootstocks or by buried specialized storage organs, like those of the coontie and the saw-palmetto.

The present endemics are either the sole survivors of plants once more widely distributed geographically or forms that have developed locally as a result of the peculiar environment of the region, just as the coontie above referred to apparently came to be.

Each of these elements of the pineland flora is extremely interesting. However, they are not more so than the various hammock shrubs and trees struggling for existence in the pinelands. Although deprived of humus, the descendants of large forest trees of the former hammock are maintaining themselves in the pinelands, but they are mere pygmies as compared with their ancestors and hammock brethren. Forest trees that commonly grow to a height of over fifty feet in the hammocks may be found within a stone's throw in the adjacent

pinewoods less than six inches tall, and full-grown trees at that. The trunks often do not rise above the rocky floor. Cringing from fear of fire, as it were, these forest pygmies develop their trunks wholly within the erosion holes formerly leached out of the limestone when hammock clothed the region instead of pinewoods, and pass their existence thus, sending out only a few leafy branches in order to carry on their necessary life-processes. These "tree-trunks" are so firmly imbedded in the rock that in order to dislodge them the rock must be broken with a sledge-hammer or split with an axe!

The areas of pinewoods apparently situated near the centers of ancient civilization—and corresponding closely to those more recently devastated by modern civilization—have had these plant relics of the former hammocks more thoroughly obliterated. In the more remote parts, which have naturally been less frequently subjected to fire, we find a more copious growth of this abnormally developed hammock vegetation than elsewhere. In a few places real broad-leaved



EROSION BY ATTRITION

THE LAPPING OF SMALL WAVES ON A CLIFF, THE FACE OF A FAULT, FRONTING BAY BISCAYNE. THE ONE-TIME SHORE-LINE AT THE BASE OF THE CLIFF, NOW SLIGHTLY ELEVATED, IS INDICATED BY THE CONCAVITY FORMERLY SCOURED OUT OF THE LOWER HALF OF THE CLIFF BY THE ACTION OF THE WAVES. NEARBY THERE IS ANOTHER EXAMPLE OF EROSION BY ATTRITION OR ABRASION. THIS IS THE CELEBRATED PUNCH-BOWL, A CIRCULAR WELL, BORED IN THE USUAL MANNER OF POT-HOLES, WHEN THE SHORE-LINE WAS SLIGHTLY LOWER. THE WELL CONTAINS FRESH—SURFACE—WATER, BUT THE BOTTOM STANDS AT SUCH A LEVEL THAT THE WATER RISES AND FALLS WITH THE TIDE.

DIFFERENTIAL EROSION

IN A LOW PART OF THE DEERING HAMMOCK AT CUTLER. AT THIS SPOT THERE WAS FORMERLY MORE HARD THAN SOFT ROCK. THIS PART OF THE HAMMOCK HAS FOR AGES BEEN SUBMERGED UP TO THE TOP OF THE ROCK-TABLES ONE, OR EVEN MORE TIMES, A YEAR. AT THE PRESENT TIME, AS FORMERLY, THE MAXIMUM HEIGHT HAVING BEEN REACHED, THE WATER RAPIDLY SUBSIDES FOR A TIME. SOONER OR LATER THE MORE RAPID SUBSIDENCE IS CHECKED, *i.e.*, THE LOWER THE WATER, THE SLOWER THE SUBSIDENCE, HENCE THE GREATER EROSION NEAR THE BASE OF THE WALLS OR SIDES OF THE TABLES, FOR THE EROSIVE AGENTS ARE MORE CONCENTRATED AND HAVE A LONGER TIME TO ACT ON THE ROCK.

trees have sprung up and have maintained themselves in spite of the fires, because there is never much tinder developed about them; but even here they have not yet succeeded in reproducing themselves in such numbers that any association approaching a hammock has developed.

It is not possible to calculate or even imagine the ratio of elevation lost through subsequent subsidence and erosion. However, erosion has been prolonged and extensive. It has been both aerial and subterranean, mechanical and chemical. Mechanical erosion has operated through flowing water on the surface, by subterranean flowing water and by the action of the waves on the shoreline. Chemical erosion has been more extensive. Rain-water charged with carbonic acid and later laden with the acids of decaying vegetable matter may either stand on the rock floor or percolate through rock by gravity or later rise as capillary water. Through all these agencies of reduction the limestone gradually gives way.

To summarize: The evidence furnished by the character of the surface erosion similar in both the hammocks and the pinelands shows that the ancient islands, now the Everglade Keys, were formerly hammock-clad. That they were formerly more elevated is evidenced by the rock floor of Bay Biscayne showing the same character of erosion as that of the present hammocks and pinelands. The fact of this one-time elevation is also established by the present existence

of subaqueous caverns in the limestone, with immense stalactites which must have been formed above the water-table.

The foregoing geologic history and the present geographic position of the Everglade Keys have conspired to produce an area surpassing in uniqueness anything within the continental United States. Situated on the end of a peninsula extending far into a tropic sea, they have received a predominance of tropical flora, and this mingling with such northern plants as have come down from the temperate mainland, an association is formed of opposing types yet living together in a habitat which has called for their utmost efforts for survival, for the solid rock floor has caused even the trees to spread their roots on its surface, as they can not penetrate it, thus becoming epipetrinous, or plants living on the rock rather than in the soil.

CASTLE PEAK

STANDING SOME THREE HUNDRED FEET ABOVE THE SURROUNDING COUNTRY, IS A PROMINENT LANDMARK, VISIBLE FROM THE TEXAS AND PACIFIC RAILWAY TRAINS SOME MILES AWAY. IT MARKS THE LOCALITY WHERE ARE TO BE FOUND THE ANCIENT TRAILS OF ANIMALS WHICH LIVED LONG BEFORE THE BIRDS AND MAMMALS.

ANCIENT TRAILS IN THE VALLEY OF THE CLEAR FORK, TEXAS[1]

By Professor ROY L. MOODIE

SANTA MONICA, CALIFORNIA

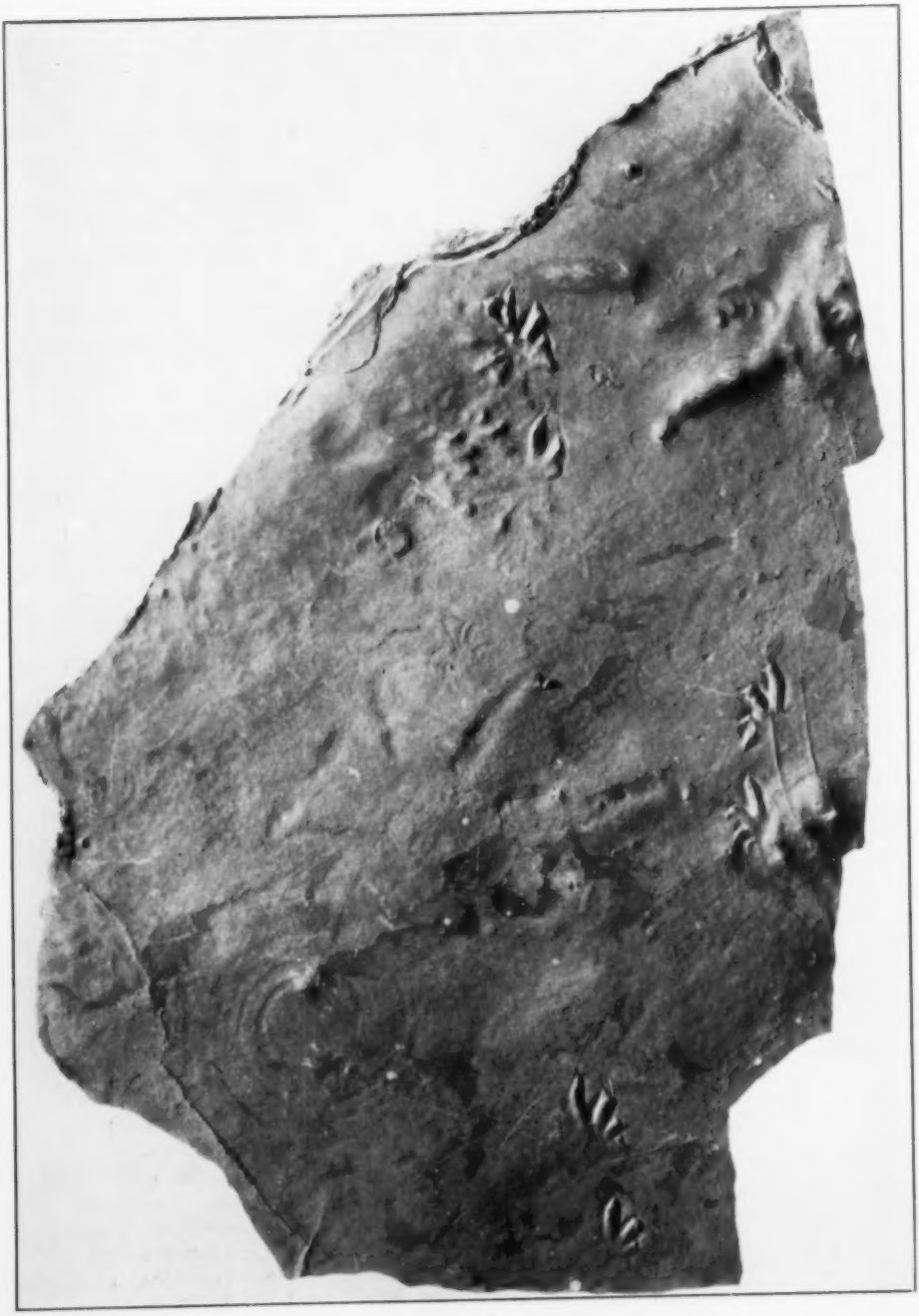
THE observing traveler sees many different kinds of trails. Winding over the sage-covered hills of western Wyoming he may see the wide trail of the forty-niners, where ox-teams, dragging heavy wagons, went four abreast. They wore down the sage brush so completely that the overland trail is still plain, after half a century of disuse. At places in western Kansas deep ruts of the old Santa Fé Trail are preserved. Man-made trails are everywhere. Hunters follow the trails of game. But the trails we went to Texas to see were none of these. They were the trails of early land creatures which lived during the time, geologically ancient, when the trail-makers themselves were the highest types of four-footed creatures in existence.

When they were making their tracks on the soft red mud the ancient Paleozoic period was drawing to its close. The time was after the closing of the great Coal Period, during the era which geologists call the Permian Age. The Permian rocks, the world over, are red, often a brilliant red, indicating, so ge-

[1] Photographs by Thomas L. Miller, San Diego.

THE VALLEY OF THE CLEAR FORK

A TRIBUTARY TO THE BRAZOS RIVER, IN ITS UPPER REACHES IS MILES WIDE BETWEEN ITS LOW TABLE-LANDS, FORMING A WELL-POPULATED AGRICULTURAL DISTRICT IN THE NORTHERN PART OF TAYLOR COUNTY, TEXAS. THE DRAINAGE IS TO THE NORTH AND EAST. TWO BUTTES, OUTLIERS FROM THE MASSIVE, LIMESTONE-CAPPED MESA, ARE PROMINENT, EXPOSING AT THEIR BASES BITS OF ANCIENT GEOGRAPHY. THE BUTTE TO THE RIGHT IS CASTLE PEAK, AT WHOSE NORTHERN BASE ARE FOUND THE REMNANTS OF THE ANCIENT, SHALLOW POND WITH WIDE, FLAT, MUDDY SHORES, CRISSCROSSED WITH MANY KINDS OF TRAILS AND STILL SHOWING ITS DEEP, MULTITUDINOUS SUN- OR MUD-CRACKS, RIPPLE-MARKS, RAINDROPS AND OTHER WEATHER MARKINGS. AS THE VALLEY CONTINUES TO WIDEN BITS OF ANCIENT GEOGRAPHICAL CONDITIONS ARE EXPOSED WHICH MUST BE INTERPRETED FROM THE FRAGMENTS OF TOPOGRAPHY REMAINING. THE OBSERVER SEES THIS VIEW FROM THE ROAD TO MERKEL, LOOKING TOWARD THE SOUTH AND EAST.



About natural size.

ONE OF THE OLDEST OF ALL KNOWN FOUR FOOTED ANIMAL TRAILS

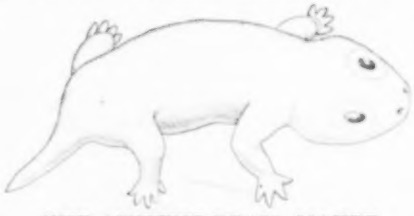
FOUND IN THE SHALES ON THE NORTH SLOPE OF CASTLE PEAK, TEXAS. THE ANIMAL MAKING THE TRAIL WAS A SMALL REPTILE-LIKE AMPHIBIAN, ABOUT TEN TO TWELVE INCHES LONG, WHO IS LIVED DURING THE PERMIAN AGE, MILLIONS OF YEARS AGO.

THE SLOPE OF CASTLE PEAK

TYPIFIES IN ITS DRAINAGE THE WATERSHED OF THE VALLEY. DRAINAGE BEGINNING NEAR THE TOP OF THE PEAK FLOWS NORTH AND EAST, BEING JOINED AT THE FOOT OF THE PEAK BY STEEP-WALLED GULCHES OR SMALL CANYONS WHOSE SLOPES WERE COVERED, ALMOST IN SHINGLE FASHION, BY FOOTPRINT-BEARING PLATES. THE MOST PROLIFIC LAYER IS EXPOSED AT THE TOP OF A GULCH COMING IN FROM THE WEST, JOINING THE DRAINAGE OF THE PEAK AT ITS NORTHERN BASE. ALTHOUGH "FROG-TRACKS," AS THE FOOTPRINTS ARE CALLED LOCALLY, HAVE BEEN COLLECTED AT CASTLE PEAK FOR MORE THAN THIRTY YEARS, YET IT IS PROBABLE THAT AT THE PRESENT RATE OF EROSION TRACKS WILL BE FOUND THERE FOR ANOTHER CENTURY.

ologists tell us, that arid conditions prevailed. Desert conditions were common. Animals to survive must be of sturdy stock. In many favorable nooks, here and there, animal and plant remains have been found, and in such a nook we found the "ancient trails," brought to the surface by erosion after having been preserved by overlying rocks for millions of years. The locality has been known for more than a quarter of a century and a few small collections have been made, but nothing of note has been published regarding the nature of these "ancient trails." We have only the trails to study. The animals themselves are unknown.

An attempt is made to reconstruct an ancient bit of geography in the land now situated in Taylor County, Texas. We



THE ANCIENT TRAIL-MAKER

WAS NOT UNLIKE THE SMALL CREATURE SHOWN ABOVE, EXCEPT THAT IT HAD SHARPER TOES.

FOUND IN THE SHALES ON THE NORTH SLOPE OF CASTLE PEAK, TEXAS. THE ANIMAL MAKING THE TRAIL WAS A SMALL REPTILE LIKE AMPHIBIAN, ABOUT SIX TO TWELVE INCHES LONG, WHICH LIVED DURING THE PERMIAN AGE, MILLIONS OF YEARS AGO.

THE LEDGE OF SHALE

ABOUT TWELVE INCHES IN THICKNESS, IS CUT UP INTO IRREGULAR PENTAGONAL COLUMNS BY ANCIENT SUN-CRACKS WHICH FORM THE VERTICAL JOINT PLANES. ON SEPARATING THE LAYERS ONE OFTEN FINDS "ANCIENT TRAILS" AT FIVE OR MORE LEVELS, INDICATING THAT SUCCESSIVE LAYERS OF MUD WERE WASHED IN AFTER THE LAYER ALREADY DEPOSITED HAD DRIED OUT A LITTLE. IT SEEMS PROBABLE THAT THIS ENTIRE BED OF MUD-SHALE WAS FORMED DURING AN EXCEPTIONAL RAINY SEASON IN A SHALLOW POND OR MUD LAKE WHICH WAS SUBJECTED TO SUCCESSIVE FLOODINGS FROM ADJACENT STEEP SLOPES.

have the records of the winds, the rains, the slow drizzles, the ripple marks, the sun-cracks and the many crisscrossing trails. Plants were very rare and of the type of the scouring rush. These things we must interpret into geographical conditions of the long ago.

Birds and mammals did not exist during the Permian, and the amphibians and reptiles were voiceless. If we could have stood near the edge of this mud flat where the creatures left their trails the sounds we could hear would be few. The winds rustled in the rough-coated rushes. There might be shrill pipings of insects. Thunder-storms may rarely have been heard, and the splash of the rain seldom. Rocks may have clattered on the hills, but of the noises which we hear now there were none. The sunshine was doubtless brilliant, and seldom veiled by clouds. At the foot of a nearby steep range of hills, the rare rains had piled up the heavier detritus carrying red clay in suspension to be deposited on the mud flat after the low gradient had slowed down the currents to a slow oozing of the liquid mud. As the slow ooze moved forward footprints made on the flat would be gently filled and covered by the layer of red mud which was later, by pressure, converted into shale—the thin bedded shale which preserved the footprints.

Castle Peak to-day marks the place where the preceding events took place. It is a fitting monument for the ancient records of former happenings. It marks the place of the fossil hunters' paradise, where ancient relics by the thousand may be secured with a minimum of effort, for most fossil hunters, like other folks, are lazy when there is no need to work. The fossil beds occur on the prop-

erty of pleasant-mannered, agreeable people. All the collector needs to do is to select what he wants, carry several armfuls of track-bearing slabs to the nearest shade and pack them away. Nowhere else in the world does such a pleasing combination exist. No other locality of limited extent yields such remarkable "ancient trails," and nowhere have such tracks been found. The steep slopes of the peak recall similar conditions in ancient times when erosion by sun and rain supplied the red sediment for the pond or small lake on whose wide shores ancient animals walked and crawled. Insects walked for short distances and took flight. Thousand-legged worms left their trails everywhere. Worms left their burrows and the four-footed creatures their tracks, but all went elsewhere to leave their remains to be fossilized, and nothing but tracks remains. In the dark belt of juniper, encircling the base of the peak, attractive camping places are found. Castle Peak is a locally famous picnic resort. Man-made trails wind in and out of the chaparral, to and beyond the bed of fossil trails. Oyster shells of Cretaceous Age have weathered out in abundance from the massive capping layer of limestone forming the beak of the butte.

Lizard-like reptiles made some of the trails. They were quick and nimble, adapted for land travel, without webbed feet. Their claws were sharp, and at places where the mud was partly dry these little reptiles left only their claw prints, sharply marked and easily recognized. Ancient salamanders, with webbed feet, ventured from the shallow pool to leave a few characteristic foot-

THE "COLUMNS" OF SHALE BREAK LOOSE

BEING UNDERMINED BY THE WEARING AWAY OF THE SUBJACENT RED CLAY, AND THE PLATES SEPARATE READILY AND SLITHER DOWN THE SLOPE, SHINGLE FASHION. THE SUN LOOSENS THE FREE INTERCALATED DUST WHICH THE WIND BLOWS AWAY OR IT IS WASHED OFF BY THE RAIN, THUS EXPOSING THE "TRAILS" ON THE SLABS. ON ACCOUNT OF THESE CONDITIONS IT IS DIFFICULT TO FOLLOW A GIVEN TRAIL FOR ANY DISTANCE OR FROM COLUMN TO COLUMN. WE READ THE RECORDS ON THE CROSS-SECTIONS OF THE SHALE COLUMNS WHICH FORM ONLY A PART OF THE EVIDENCE. THE DARK AREAS ON THE PLATES IN THE PICTURE ARE A DEEP RED. THE LIGHT MOTTLINGS AND EDGES OF LIGHTER COLOR ARE PALE GREEN OR GRAY.

THE PIECES OF SHALE

ON THE SLOPES OF "TRAIL GULCH" BORE MANY FOOTPRINTS OR WEATHER MARKINGS FROM WHICH WE HAVE READ THE STORY OF THIS FAR-OFF TIME. THE FOOTPRINTS WERE TRAILS OF FOUR-LEGGED ANIMALS, REPTILES AND AMPHIBIANS, OF INSECTS, OF CENTIPEDES, BURROWS OF WORMS AND OTHER TRAILS OF A DOUBTFUL NATURE. THE WEATHER MARKINGS TOOK THE FORM OF RAINDROPS, SUN-CRACKS, DRIZZLE RUN-OFF, WIND MARKINGS AND LOW, BROAD RIPPLE MARKS. WITH A SMALL BRUSH ON SOME OF THE PIECES, NOT CLEANED BY RECENT RAINS, ONE COULD EXPOSE INTERESTING EVIDENCES OF ANCIENT HAPPENINGS. AS THE SUN WENT TOWARD THE WEST CASTING SHARP SHADOWS ONE MIGHT SEE SMALL FOOTPRINTS ON SLABS MANY YARDS AWAY. THIS IS THE FOSSIL HUNTER'S PARADISE, WHERE WITH SCARCELY AN EFFORT WONDERFUL SPECIMENS COULD BE OBTAINED.

prints, entirely different from those of the aggressive reptiles. Long-legged, two- and three-toed reptiles, otherwise unknown, left their tracks in the soft mud. Two-toed animals [illegible] not otherwise known to have existed during the Permian.

Accompanying the four-footed creatures and doubtless serving as their food were sharp-shinned insects, leaving a clearly marked trail. Centipedes and their relatives, the millipeds or thousand-legged worms, scurried across the mud, often getting into difficulties in the soft ooze. Soft-bodied worms left their tubes. The surface mud was so fine and soft that many minute trails appear, suggesting a world of life otherwise unknown. Tiny tracks offer tantalizing subjects for speculation.

While the drainage from Castle Peak to-day is toward the north and east it seems probable that in Permian times the highlands were toward the west and the drainage was toward the east and south. The pond or small lake existed only during the wet season, and for only a limited time. This shallow body of water lay near where now is the northern foot of Castle Peak. The mud flat where the footprints were made lay between the pond and the foot of the hills which furnished the sediment.

The sun shone hotly on the exposed

THE THIN SHADE OF THE JUNIPER

GAVE WELCOME RELIEF FROM THE HOT MID-SEPTEMBER SUN IN THE TRAIL GULCH DURING THE PACKING OF THE COLLECTION. EACH SHALY PLATE WAS WRAPPED IN A HEAVY NEWSPAPER COAT AND TIED, THEN PACKED WITH OTHERS IN A PAPER CARTON. ON REACHING TOWN ALL CARTONS WERE CAREFULLY PACKED INTO A WOODEN SHIPPING CASE TO PROTECT THE THIN PLATES FROM BREAKAGE.

mud flat and huge sun-cracks developed, so deep that they cut through all the layers of mud and so wide that they are still evident, cutting through the entire bed, converting the shale into columns of an irregular pentagonal shape. With the drying up of this small area the animals went elsewhere to seek their food—possibly to an adjacent pool near whose borders they continued their brief span of life, leaving their bodily remains no one knows where.

More than a dozen species of footprints have been recognized, representing two types of primitive amphibians, and ancient reptiles. The technical details will be published elsewhere. One easily characterized species, originally described from the Grand Canyon of Arizona, is found in the Castle Peak beds; all the others are new to the sci-

Photograph by Dr. F. C. Clark.

TRACKS OF A SEA-GULL

ON RECENT MUD IN SANTA MONICA, SHOWING HOW SUN (OR MUD) CRACKS FORM. THE TRACK IN THE MIDDLE HAS ONE CLAW MARK MOVED BY THE CRACK.

THE MARGINS OF THE ANCIENT POND

AND ASSOCIATED MUD FLAT ARE MARKED IN THE ROCKS BY THE "PINCHING OUT" OF THE SHALE LAYER. AT THE PHOTOGRAPHER'S HAND THE LEDGE HAS BECOME VERY THIN, AND IT GAVE OUT ENTIRELY A FEW FEET FARTHER TO THE RIGHT. FOOTPRINTS WERE RARE HERE BECAUSE THE MARGINS OF THE MUD-FLAT WERE DRIER AND DID NOT SHOW OR TAKE MARKINGS SO READILY AS THE SOFTER AREAS.

ence of ichnology, as the study of fossil footprints is called.

My first acquaintance with the Castle Peak fauna was when my good friend, Dr. F. C. Clark, of Santa Monica, California, showed me a collection of footprints from those beds in Texas which have become known as the Castle Peak beds. Our trip to the deposit was made possible through aid from the department of geology and paleontology of the University of Chicago, and from the Los Angeles Museum. The trip involved an auto ride of nearly three thousand miles, which was made safely. The fossilized "ancient trails" will still yield new facts to further study, and it is our hope to go again to Castle Peak to search out further evidences of these very ancient "trail-makers."

THE ELIMINATION OF THE MALE SEX IN THE EVOLUTION OF SOME LOWER ANIMALS

By Dr. ARTHUR M. BANTA

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Sex and sexual reproduction appear almost as essential and fundamental in the plant and animal world—both with the simpler and higher forms of life—as nutrition and respiration. Sex and its differentiations are indeed some of the most useful characters for the study of the course of evolution. In some groups of living organisms, *e.g.*, certain insect and crustacean groups, the peak of differentiation apparently lies in the highly specialized secondary sexual characters.

Every one appreciates the fact that the term sex implies two sexes, the female and the male, and that the two sexes in the higher forms differ profoundly not only in the germ glands, but in secondary sex structure, in physiological characters, even in psychological and behavior characteristics. The writer wishes to point out in this brief paper a fact which is perhaps less appreciated—namely, that in certain groups of animals, particularly with the Cladocera (with which he has some familiarity) the male sex has in the course of evolution assumed less and less importance until now one can definitely point out that in certain forms the male is apparently in course of elimination—this sex has indeed been quite eliminated in a few Cladocera—and that *this elimination has actually proved advantageous to the forms involved.*

The Ancestral Type

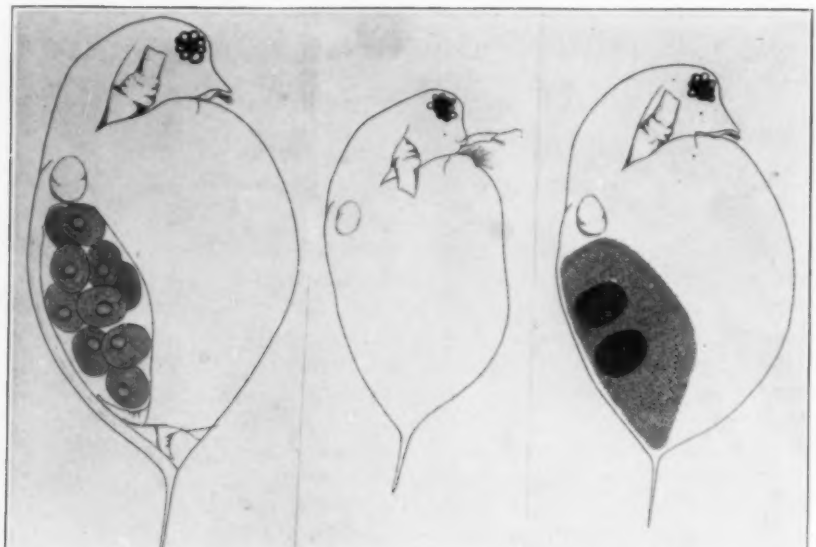
Cladocera are a group of the lower crustaceans and hence may be thought of as cousins of the lobster and shrimp. They are popularly known as "water-fleas," although they are quite innocent of any real relation in structure or behavior with their unpopular namesake. These small animals live in fresh-water lakes, ponds and puddles the world over. From analogy with other organisms, we must believe that their ancestral form, like most plants and animals of to-day, reproduced entirely by sexual reproduction (Fig. 2 A). At the present time, however, no Cladocera forms are known in which sexual reproduction is the exclusive means of reproduction. Indeed, we shall see that sexual reproduction has assumed a very minor rôle in many of these forms and that it, together with the male sex, has been entirely dispensed with in some forms.

The Life History of a Daphnia; the Intermediate Type

A few details of the life history of these animals may perhaps prove of interest and be useful in presenting the striking situation the writer wishes to portray. Many present-day Cladocera, such as the cosmopolitan *Daphnia pulex*, live in small temporary ponds. In general, young individuals hatch in the early spring from sexual eggs produced by females (Fig. 1 C) and fertilized by males (Fig. 1 B) during the previous open season. These young are all females.

Parthenogenesis

In a few days each female becomes an adult 1 to 2 mm in length (Fig. 1 A), and produces eggs which she lays into her brood chamber (a cavity within the dorsal region of the animal). These eggs do not require fertilization. They de-



A. B. C.

FIG. 1

A. Female *Daphnia* with parthenogenetic eggs in the brood chamber. The swimming antennae are not completely shown.

B. Male *Daphnia*.

C. Female *Daphnia* with sexual or "winter" eggs in the brood chamber. These eggs are destined to be cast off in the protective egg-case or ephippium.

velop promptly and are discharged from the mother's brood chamber in forty-eight hours (at 70° F.) as young *females*. These young females themselves produce young within seven to ten days.[1] Successive clutches of young from a given mother are released each alternate day. The numbers in a clutch may reach thirty or even seventy. Under exceedingly favorable conditions a single mother may readily produce three hundred to six hundred young, all of which are females and are produced parthenogenetically—without any male intervention whatever. However, these extremely favorable conditions are seldom completely realized in nature, although they may be in laboratory cultures. But with even moderately favorable conditions, the number of descendants from a single mother and her daughters, etc., soon reaches prodigious proportions. Of course there are certain natural checks which tend to restrict the increase of population. Small fish, predacious insect larvae and other animals, even the lowly fresh-water hydra, prey upon Cladocera and limit their numbers so that many of them do not live to produce such large numbers of young. Further, many of the ponds which they inhabit undergo excessive evaporation and become much reduced in size. If not abnormally restricted in numbers by enemies, by food supply or by other factors, the Cladocera population soon becomes excessive, especially if the pond has been subject to recession.

[1] These time periods refer to ordinary laboratory temperatures (68° to 70° F. or about 20° C.). At lower temperatures the generation cycle is much lengthened; at higher temperatures greatly shortened.

Sexual Reproduction

Excessive population (which we shall refer to as "crowding") results in an

accumulation of the animals' excretory products. This accumulation of excretory products both in nature and in laboratory cultures results in the production of *male* young from the very eggs which under more favorable conditions produce only females. Extreme scarcity of food, which is also frequently a result of crowding, causes the females (sometimes apparently every female of the population of many thousands) to produce a markedly different type of egg. This is the sexual or so-called winter egg which can not hatch unless it is fertilized. After a period, sometimes less than a week, during which the sexual eggs are produced and fertilized, the entire Cladocera population is often destroyed by the stress of conditions—depletion of the pond, scarcity of food, the accumulation of excretory products, etc. If the pond does not reach complete drought or is replenished, a few may survive this period of stress and replenish the stock by the usual parthenogenetic (non-sexual) reproduction.

The fertilized eggs must have a resting period before they will hatch. This period may be prolonged for many months during which they may become dry or frozen without injury. They may hatch in the autumn with the replenishment of the pond by rains or they may remain dormant and not hatch until the following spring. This life cycle is diagrammatically shown in Fig. 2 B.

The utility of the sexual or winter egg in the life cycle of these animals is obvious. It tides the race over a period which neither the active animals nor their parthenogenetic eggs can survive. It hatches when favorable conditions again arise. Sexual eggs occur only two in a clutch in most Cladocera and only a small percentage hatches, under natural conditions probably, in most cases, less than 1 per cent. The adaptive advantage of the production of the sexual eggs at a time of crowded population and hence in great numbers is obvious.

The Advantages of Parthenogenesis

The utility of parthenogenetic reproduction in the life cycle is only a little less obvious. Whereas sexual eggs occur only two to a clutch and very few hatch, parthenogenetic eggs in many species may occur in clutches of twenty or many more. Nearly every parthenogenetic egg produces a viable young. Further, during active parthenogenesis, the population may be and usually is exclusively female. Here *every* individual is productive of young. If males did occur during this period they would be quite superfluous.

Parthenogenesis, then, is a method which accomplishes rapid multiplication and, with every individual of the race a productive *female*, the rate of population increase under favorable conditions is extraordinarily rapid indeed. This rapidity of parthenogenetic reproduction is an important advantage for two reasons. (1) Many Cladocera habitats are small temporary ponds which become dried up or otherwise unsuitable for Cladocera inhabitants early in the summer. A rapid multiplication of the population (derived from the few sexual eggs which hatch in the early spring) is essential if this favorable environment is to be utilized. Further, Cladocera, like all other living organisms, are subjected to relentless competition. Their failure promptly to utilize favorable environmental conditions would mean correspondingly increased success to competing species, reduced opportunities for themselves as a lagging species and reduced numbers of females (all of which may bear sexual eggs) and males to insure carrying the species over the ensuing unfavorable period. Cladocera species do vary in the rapidity of their parthenogenetic reproduction, but their world-wide distribution and their occurrence from the arctics to the tropics in nearly every pond apparently suitable for their habitation attest to their success in meeting competition and in sur-

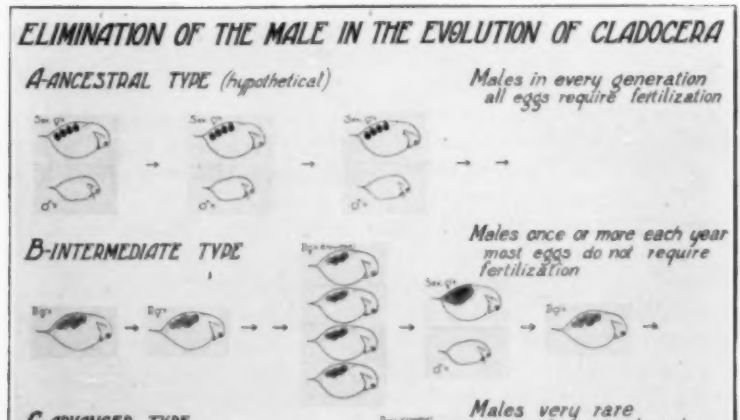


FIG. 2

A. The hypothetical ancestral type. Presumably marine and reproducing exclusively by sexual reproduction, males occurring in every generation.

B. The intermediate type. Lives in fresh-water ponds and temporary puddles. Parthenogenesis is the prevailing method of reproduction but males and sexual reproduction occur at one or more periods each year.

C. The advanced type. Lives in lakes and more nearly permanent ponds. Parthenogenesis is almost the exclusive method of reproduction. Males and sexual reproduction occur only under exceptional conditions of stress.

D. The more advanced type. Lives in lakes in mild climates and perhaps in permanent marshes. Parthenogenesis is the exclusive method of reproduction. Males do not occur.

E. Most highly specialized type. Lives in temporary ponds like "B" above. Parthenogenesis is the exclusive method of reproduction. Males do not occur. This type is unique in that it has retained the "winter" egg, which, however, is here a pseudosexual egg and not only does not require fertilization but can not be fertilized. It is apparently the type best adapted for continued existence in transient ponds.

viving unfavorable periods. (2) Rapid multiplication during the favorable period of the life cycle is a further advantage since it provides large numbers of females and males for producing the fertilized sexual eggs when the less favorable period comes and the sexual or winter egg alone can provide the means for continuing the race until another favorable period arises. The production of vast numbers of sexual eggs is essential to the perpetuation of the race. The sexual eggs are eaten by other animals; quantities are smothered by débris; vast quantities become stranded on the dry margin or the bottom of the pond, if it becomes completely dried up, and may be carried away by wind or other agencies or destroyed by other means; finally, under the most favorable conditions the hatchability of these sexual eggs is very poor. Except for the prodigious population of these animals, which parthenogenesis brings about in the comparatively brief favorable period, it is difficult to conceive that sufficient numbers of sexual eggs could be produced to insure carrying the species over from season to season. Here, as in many phases of nature, the opportunity ordinarily arises but once. Failure to utilize the opportunity for the production of the fertilized sexual eggs when it comes would mean destruction of the species in the pond in question. But such failure probably seldom occurs. These animals are so attuned to their ever-changing environment that the approach of unfavorable conditions in itself operates to bring about males and sexual reproduction. Thus it appears that the rapidity of parthenogenetic reproduction, especially promoted by an all-female population, is of great advantage in enabling Cladocera to utilize an environment while it is physically available—before the pond becomes dried up; and while it is biologically available—not largely preempted or depleted by competing species, and further to provide for the timely production of sufficient numbers of the fertilized sexual eggs to insure the perpetuation of the race.

The life history just cited as typical for the common *Daphnia pulex* with certain minor variations may apply to the vast majority of present-day Cladocera species. The decreased occurrence and lessened importance of the male sex during the greater part of the yearly cycle of these animals, as compared with most other living organisms, is apparent. It is equally apparent that there is a correspondingly increased rôle played by the female sex in the life cycle, during the greater part of which cycle the female carries on reproduction quite without male cooperation.

Three general groups of Cladocera species, which have progressed further in the elimination of the male sex than in the illustration above, show important modifications of the life cycle. These modifications of the life cycle can be more briefly stated than the general life cycle discussed above.

The Advanced Type

The first of these more highly specialized groups contains species like *Simocephalus exspinosus* which in nature less often have males and sexual reproduction than does *Daphnia pulex* of the intermediate group just discussed (Fig. 2 C). A statement for *S. exspinosus* may typify this "advanced" type. This species lives in general in cleaner ponds and more generally permanent ponds than many of the species belonging to the group previously discussed. It has a fairly rapid reproductive rate but, for some little-understood reason, less often attains a condition of extreme crowding. Possibly there is some natural check which prevents the development of acute overpopulation which so frequently occurs in the former group. It might readily be that they are less omnivorous in their food habits and that their numbers are held in restraint by food lim-

itations before extreme overpopulation occurs. There is, indeed, some positive evidence in support of this supposition. However this may be, the facts remain that *S. exspinosus* on Long Island lives in general in ponds (1) which contain less organic matter and are much less filled with bacteria and other lower organisms; (2) in ponds which are permanent or more nearly permanent, and (3) that in our experience this species in nature has very rarely been found producing males, while we have never seen the sexual eggs in nature. Yet individuals of this species may be found the year round. During the entire open season this species normally produces only parthenogenetic eggs following which a few parthenogenetic or reproductively inactive females live over winter under the ice and begin active parthenogenetic reproduction again in the early spring. Hence this species in suitable ponds may apparently continue indefinitely by parthenogenesis and entirely without males in the population. It is, however, capable of male and sexual-egg production and may readily be caused to produce both under appropriate laboratory conditions (crowding of the mothers for male production and scarcity of food for sexual-egg production). It may, however, also produce both these perquisites for sexual reproduction in nature, else its recurrence in some ponds which have become dry during the preceding season is not readily accounted for. In our experience males have been found in only one pond, which at the time of occurrence of males of *S. exspinosus* was heavily crowded with two different races of *Daphnia pulex* and contained moderately large numbers of two other species (including the *S. exspinosus* under discussion). The *Daphnia* races were producing vast numbers of males and sexual eggs at the time the less abundant species were found to be producing a few males. Probably sexual eggs of *S. exspinosus* also occurred but escaped observation, inasmuch as the pond became dry and the species nevertheless reappeared the following spring.

The situation in brief is this. *S. exspinosus* lives under circumstances which ordinarily permit it completely to dispense with males and sexual reproduction. Under exceptionally adverse circumstances, however, it may and does resort to sexual reproduction and thus the race is carried over by means of fertilized eggs to the next period favorable for its active life. Fig. 2 C is an attempt to diagram this life cycle.

The More Advanced Type

Another group of Cladocera, the "more advanced type," consists of certain lacustrine (lake-inhabiting) and probably some marsh-inhabiting forms, like *Bunops*, which live in more temperate climates. These forms occur the year round and are not known to produce males. They presumably have only non-sexual reproduction (Fig. 2 D). The writer has had little experience with these forms. It would be exceedingly interesting to test them in laboratory cultures to see if they have lost the capacity for male and sexual-egg production.

The Most Highly Specialized Type

The height of adaptation in the elimination of the male is seen in a unique form of the highly polymorphic *Daphnia* group found on Long Island. This constitutes the "most highly specialized" type (Fig. 2 E). This development is accompanied by a special adaptation to environmental conditions such as occur in small temporary ponds, like those inhabited by the type of the ubiquitous *Daphnia pulex* of the first group discussed. In this, the final group of Cladocera to be discussed, not only have the male sex and sexual reproduction been eliminated but, *mirabile dictu*, the winter egg has been retained. But, whereas in other Cladocera forms the winter egg is a true sexual egg and must be fertilized in order to develop, in this

form the winter egg develops without fertilization, *i.e.*, it is a *pseudosexual* egg. So complete is the structural and developmental resemblance of this pseudosexual winter egg to the winter egg (the true sexual egg) of other known Cladocera forms that we at first questioned its apparent development without fertilization. However, laboratory experiments demonstrated that this winter egg does develop, after the usual "resting" period, in spite of the fact that no males had been present in cultures in which it was produced. Considerable search among the population in nature and extensive laboratory experiments had already failed to reveal a single male of this cladoceran type. We must conclude that this form does not produce males. Males of other closely related *Daphnia* forms did not succeed in fertilizing this egg so that we conclude further that it can not be fertilized. Of still further interest is the fact (demonstrated by Dr. Franz Schrader, of Bryn Mawr College) that this pseudosexual winter egg in its development cytologically quite resembles the development of the ordinary parthenogenetic Cladocera egg. Hence it is apparent that in this form the winter egg, with its attendant advantages for the carrying over of the race from one favorable period to another, has been retained and yet the male sex has been entirely eliminated.

Cladocera happen to be better known to the writer than other groups of organisms. It is known, however, that among plants the common and very successful dandelion (among others) has dispensed with sexual reproduction. Similar examples from the animal side are rotifers and plant-lice, which may have only female population and uninterrupted parthenogenesis for long periods; and, as a more extreme case, certain gall-producing wasps which have only parthenogenetic reproduction and the male (which is here a rarity indeed) is quite functionless, both the sexes having lost their sexual instincts.

SUMMARY

The writer has attempted to show that with the lowly water-flea, as with certain plants and other animals, the male sex and sexual reproduction have in general come to assume a much smaller than the usual rôle and a smaller rôle than must have been the case in their ancestral forms; that in certain forms, the "intermediate" type, males and sexual reproduction have been eliminated for the greater part of the life cycle (though they, with the resulting winter eggs, do occur in periods of stress); that in another, the "advanced," group inhabiting permanent ponds, males and sexual reproduction occur with rarity, the animals under favorable conditions being able to live from year to year without resort to the sexual or winter eggs, although the species still possess the capacity for male and sexual-egg production and do produce these perquisites for sexual reproduction on occasion; that in another, the "more advanced," group inhabiting lakes which do not become dry or frozen, all individuals are apparently female, males and sexual eggs being unknown; and that finally we have a "most highly specialized" type, inhabiting temporary ponds, which not only is without the male sex but asexually produces the functioning winter egg which serves to carry the race through drought and winter.

This restriction and even elimination of the male sex seems attended by certain advantages. These animals by the rapid method of parthenogenesis (1) are able to take advantage more quickly of a favorable, perhaps transitory, environment and (2) are better able to meet the competition of other species. Furthermore, since females alone can produce eggs, the all-female population is a decided advantage (3) for quickly utilizing favorable conditions, (4) for providing vast numbers of females and males for the production of the fertilized sexual eggs, when the occasion arises, and (5) in the most highly specialized form for producing adequate numbers of the pseudosexual winter eggs.

REPETITION IN THE BREAKING OF HABITS

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NEARLY two years ago I put before the American Association for the Advancement of Science the outline of a method for dealing with undesirable habits, based on a theory with regard to the rôle of repetition in habit formation: a theory which is almost the reverse of that which William James impressed upon American psychology so thoroughly that it has been practically accepted as axiomatic. Since publishing this outline,[1] I have received friendly suggestions from various psychologists as to the priority of other authors in formulating the theory, but I am still unable to see that any of these other authors would have been understood to have suggested the hypothesis which I am presently holding unless the reader were previously familiar with the hypothesis. The controversies over the function of frequency have been, so far as I am able to understand them, limited to the questions whether frequency, *per se*, is the sole factor in habit formation or but a primary factor among others or merely a minor factor. No one seems to have doubted that repetition *per se* is a factor. Of course, the specific question as to the number of repetitions does not enter here, for no one has ever denied that a single performance may in certain cases fix a habit. The point has been that it is the *doing* of an act which contributes to making the act habitual; and that if a single doing is not sufficient, several or many repetitions may be. Just what constitutes the *doing* of an act has not always been carefully scrutinized, but very frequently, doing or acting has been considered naïvely in the simple physiological sense. The vogue of the "conditioned reflex" terminology, with the accompanying amazingly naïve selectiveness of interpretation, has intensified this unanalytic attitude on the part of contemporary psychologists, or some of them.

In brief, I have pointed out that the theoretically possible rôles of repetition, *per se*, in habit formation, are three, and I have for convenience designated them as the *alpha-hypothesis*, the *beta-hypothesis* and the *gamma-hypothesis*, respectively. Stated somewhat carefully, the alpha-hypothesis is as follows: "A response (that is, even a single response) to a given stimulus pattern definitely increases the probability that on the recurrence of the same, or substantially the same, stimulus pattern, the same, or approximately the same, response will occur." Stated concisely, the beta-postulate is that response, in itself, has no effect on the probability of the same stimulus pattern producing the same response, and the gamma-postulate is that response decreases the probability. Adopting the beta-postulate as an obviously fertile one, I have therefrom deduced the hypothesis that repetition may be employed in the dissolving or breaking of habits as well as in the formation of habits, and by a simple comparative method formulated a tentative method for such employment. I will not repeat the details, which may be found in my original article along with the results of the first attempts at application.

Various individuals have since made trial of the method I suggested, some in consultation with me, some without. Their results have been as varied as might be expected. Technique is all-important, and must be based on careful psychological analyses (not psychoanalyses) of the cases. My surmise that dif-

[1] *Science*, 67: 360–362, April 6, 1928.

ferent ages of patient and different types of habit require different techniques is apparently verified. Dr. Blanche Weill seems to be attaining success in the treatment of enuresis in children; others have been discouraged after a few trials. The technique with this particular habit seems still crude. Dr. John Bentley has achieved remarkable success with a group of confirmed finger-nail biters of college ages. A few weeks of practice for a few minutes a day suffice to let the nails grow out to normal length and the habit is broken; but the patients being then left to themselves, many relapse, as might be expected. The follow-up treatment for this type of case is manifestly of great importance. For many types of case, the scales of frequency, duration and character of follow-up practice need to be worked out.

Thumb-sucking, in four- and five-year-old children, yields interesting results in the few cases where the method has been applied. The children grasp the method and seem to understand its purpose. Strong obstacles develop; the child devises ingenious methods of diverting its attention from the important details during the practice period, etc. These are overcome by the patience and tactfulness of the experimenter, and the habit rapidly dwindles to a low stage, where it remains. The explanation apparently is that the child loses the incentives which have previously been supplied by the mother's scoldings; the habit becomes almost negligible and the child finds no bad results from it, and hence loses interest in overcoming it. Technique here is needed.

Sexual perversions in adolescents and adults seem to offer the easiest problems of all, perhaps because the individuals are anxiously interested in breaking them. In the few cases where I know it has been tried, masturbation and homosexual practices yield readily to treatment provided the treatment can be applied under the direct supervision of the psychologist (which of course is not possible in some cases), and relapses are not difficult to forestall.

Some applications have been made to stammering cases, and these seem to offer opportunities for useful work, but the development of the adequate technique is still a formidable task. From the results with one case, of typical sort in the young adult, which I have now on my hands, I believe the technique can be developed. Even brief treatment has produced a remarkable improvement, greater than I have ever obtained in any case with other methods. I am inclined to think now that the most economical and adequate treatment will occupy a few days at a time, these times being separated by several weeks. Since in no case do I expect a cure or decisive improvement inside of a year, whatever method be employed, the working out of the time schedule for the treatment is an important matter. It is probable that in many other types of case time is an important element, and the most adequate utilization of the time-stretch is hence a vital problem.

It is to be understood, of course, that the techniques we are using and the better techniques we are seeking can be adequate only against the habit as habit, and will suffice only in those cases in which the original causes have ceased to operate, as they have in very many cases of stammering, for instance. Where the primary causes are still operating, not only must the habit be broken up, but the causes must be ferreted out and eliminated. It appears, however, that the technique necessary to break up the habit offers excellent opportunities for correlated work in discovering the causes, where these are still operating.

The importance of technique is illustrated by the report of Dr. G. Wakeham[2] of his own attempt to apply the outlined method to the elimination of certain errors which he habitually made in the

[2] *Science*, 68: 136–137, August 10, 1928.

rendering of certain passages of the Bach-Taussig Toccato and Fugue in D minor. The selected passages were played ten times daily, with the wrong notes deliberately and attentively put in, the other conditions of the method being fulfilled. On the fifteenth day the whole piece was played without error. After several errorless performances Dr. Wakeham attempted to demonstrate his success to one of his pupils—and played the passages with his habitual errors.

Now, I am not claiming that I would have predicted just that result, for my knowledge has developed slowly in respect to this hypothesis and method. But it is now fairly clear that the technique employed by Dr. Wakeham was not the most adequate. What I would now prescribe would be to follow the successful performance achieved without audience by a practice performance with the errors, in the presence of the pupil, and then to attempt a perfect performance in his presence. If this should be followed by an error-practice performance in the presence of a small group, I venture to predict that a successful perfect performance could be expected before an audience. The conditions of erroneous performance in the past and the mental attitude towards the errors *in the presence of others* have been influential in this case. In the case of a novice or even an advanced student who has habitual errors to correct but who has not felt humiliated by them the conditions might be much simpler.

I can not refrain from mentioning here an amusing case, on which my data are not complete. A lady in a distant state described to me in a letter a certain morbidity with which she was afflicted. Apparently she dipped into medical books and journals, for she wrote that when she read about any of the bodily organs, she had unpleasant feelings in (or referred to) her own organs: and if she read a description of symptomatic feelings she experienced those symptoms. She indicated that she knew it to be morbid imagination, but nevertheless it was inconvenient.

I explained to her, of course, that on such sketchy data and no possibility of supervision I could not make any definite prediction or promise of results, but I suggested a technique which was well worth trying. I suggested that each day she select a set of symptoms, and then for a few minutes revel in them. I gave her detailed instructions as to mental attitude (or thought processes, if you prefer that term), and warned her that persistence for some weeks might be required. A few months later she wrote, in effect, that she had had a terrible time with the method, but had stuck to it, and was now entirely free from her morbid troubles. This, of course, sounds like a patent medicine testimonial, but I have not had time to follow up the case more definitely.

Some cases of successful application of this method have been reported by others, and many cases will be in shape to report on before long. There is, however, a field of application which opened up accidentally which I wish to mention because of its theoretical implications as well as its practical possibilities and also because I have results to report obtained only on myself, and I would like to invite others who may be interested to make trials. Like many other people, I forget names of persons and places, and have had a number of vexatious habits of forgetting specific names. I can always find amusing psychoanalytic explanations for the forgettings, but that doesn't help matters any. By accident, I thought of an application of the method under discussion, and since then have been having a good time demolishing my specific amnesias as fast as they present themselves. Perhaps a description of the first case may make the conditions clear.

On the boulevard between Baltimore and Washington there is a small settlement where the boulevard makes almost

a right-angle turn. I had occasion during the winter of 1927–28 to drive the boulevard one or more times a week, and noted that in approaching this spot I never could recall its name, nor could I recall it at other times. On various trips, after passing the place, I tried to memorize it by different methods, including the method of repetition, but without success. Last fall, as I approached the turn, it occurred to me to try the negative method. Upon reading the name, therefore, I tried to forget it—an attempt of a sort which most of you know is most baffling. This, however, did not last more than a minute (or a little over a half mile), as I could check later. I have never had the least difficulty in remembering *Beltsville* since. The sagacious critic will point out that in the effort to forget the name I was giving exceedingly good attention to it, but the fact remains that by this brief effort I accomplished what prolonged and repeated effort of the positive type had failed to bring about.

Since that time I have applied the method to other names with one significant failure. This summer in Algeria I passed the striking boiling springs near the railroad from Constantine to Alger which are named in English translation the "baths of the damned." Shortly afterwards I found that I had forgotten the Arabic name and had to look it up in a guide-book. A little later I had again forgotten it, so after looking it up again I made effort to forget it but this did no good, and I finally dropped the matter. However, in writing this paragraph, I find that *Hammam Meskoutime* comes to memory immediately. This failure under quite different conditions from those of my other trials suggests that there may be a line of useful experimental work to be discovered here.

This application, aside from possible practical values, suggests an explanation for these curious and vexatious forgettings, namely, that positive effort to remember a name which for one or another reason does not recall immediately may make future recall still more difficult, even impossible. At any rate, whenever I disremember something, I now happily dismiss the vacancy as quickly as possible. Here again, James came close to suggesting the method, but not the theory. If my observations should be confirmed, it will be evident that the Freudian doctrine of repression needs more than a little revision.

Enough of these instances, which of course are not experimentally valid and prove nothing. This year I am returning to my laboratory after two years of wandering in the wilderness. I plan to attack the problems of the alpha, beta and gamma postulates from as many directions and as fast as possible. As I said at the beginning of this paper, I think we have here a theory which is either quite absurd or else has far-reaching implications. We might as well face the possibility that we shall eventually be forced to the conclusion that no habit formation is possible without ideational activity, or thinking; a conclusion to which the so-called "conditioned reflex" experiments, in my limited understanding of them, already point. But of course, if we should admit that the white rat thinks, that does not imply that his ideational processes are of the advanced type of humans (or of *some* humans).

The bearing on the theory of dreams I have indicated in my primary article, and I have had no opportunity to make any observations on that point.

In regard to the therapeutic applications, I must point out that I have at present neither expectations nor hopes of the development of methods which can be applied by the layman or by the psychiatrist untrained in psychology. The method, as it looms up, involves delicate psychological points of ideation and motivation which demand expert

acquaintance with the psychology of the learning process and with many other details of mental life. The psychological principles, I apprehend, must be applied to each case after careful study. I do not find that it is easy for the psychologist (in which class I place myself) to grasp the conditions involved, and many seem to have assumed that the basal principle involved is simply that yielding to a habit tends to break it, which is really more nearly the opposite of the actual principle.

In criticizing the method in its crude state, many theoretical objections have been raised by various psychologists, and the possibilities of interpretations on the basis of various other hypotheses, including the psychoanalytic ones, have been pointed out. I do not think that at the present stage of the game these are important, although they may be later. For the present, I am willing to waive interpretations and go after experimental results. We have here certainly something new, however closely it may have been missed in the past; something which is intensely interesting, to me at least, and something which opens new experimental possibilities. To a prosaic psychologist like myself, this leaves nothing to be desired but work.

COLOR IN SCIENCE AND POETRY

By Dr. GEORGE R. STEWART, Jr.

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WHEN the perfect history of English literature is written—a volume which will bear as its imprint *Jerusalem, the Golden*—I feel sure that it will contain some such sentence as this: "One of the important events in the history of poetry during the nineteenth century was W. H. Perkin's discovery in 1856 of phenylphenosafranine ($C_{27}H_{25}N_4Cl$)."

To understand why this respectable chemist, Mr. Perkin, may some day be ranked with Keats and Browning we must skip nimbly back a few centuries—let us say, to the time of that so-called Father of English Poetry, Master Geoffrey Chaucer. None of us can read Chaucer's poetry much without becoming strangely conscious of the, to us, naïve and childlike repetition of a few primitive colors. Hardly ever do we find any distinction of hue or shade. The "floures white and rede" bloom, and bloom again in almost every mead. Now and then they become "blew and white and rede" and once, to our astonishment, actually "white, blewe, yellowe, and rede." In this same stanza is also mention of green and silver, but with this one great burst of dissipation—it occurred in his youth—Chaucer reached his limits as both nature observer and colorist, and thereafter maintained an impeccable respectability. To the modern mind Chaucer appears to have developed his color sense about as far as the child who with his crayons creates a blue-blue sea, a yellow-yellow beach and a green-green tree without idea of more subtle conceptions.

For contrast let us look at some of Miss Amy Lowell's work. This procedure will be greatly to Chaucer's disadvantage. To begin with, we notice that the modern poet has lost nothing which the older poet had; red can still be as red and white as white as in the flowers by the Canterbury road:

> High-footed cups for green wine,
> And incense-burners yellow as old Llama books
> With cranes upon them.
> Blue porcelain for the Altar of Heaven,
> Yellow for the Altar of Earth,
> Red for the Altar of the Sun,
> White for the Altar of the Year-star.
>
> —*A Legend of Porcelain.*

But, over and above this, modern poetry can show a new technique of hue, tint and shade; red is not always red. In a few of Miss Lowell's poems, with no attempt to be exhaustive, I have listed seventeen varieties of redness. There are "crimson butterflies," "peach-bloom silk," "dawn-red wine-cups," "vermilion fishes," "cocks with rose-pink legs," "ochre-red sails," a "scarlet dress," "pink water reflected from the carmine-tinted mountain summits," "rose-red light," "blood-orchid tips of mountains," "copper," "maroon," "ruby," "salmon," "carnation," "magenta." These are not merely words used for the sake of variety, but they actually suggest different, often strikingly different, mental images, all of which Chaucer was wont to group meanly under the one word *red*.

Since no one can successfully maintain that Chaucer really was an unsophisticated child of a simple-mannered century, the explanation of his crude technique must be sought elsewhere. Once considered, the question is not difficult. His poverty-stricken color vocabulary does not prove that he had no sense of hue, or even that he did not care to play with nuances as well as any imagist. But he could do no other. Like many another medieval man of

genius he was cabined close by lack of tools. He was an Abelard studying philosophy without Aristotle, a Roger Bacon scanning the heavens without a telescope. In short, Middle English simply did not contain the necessary color terms. Those words which give the glow of multicolored light to the pages of a modern poet were in the fourteenth century either not yet invented or not yet metaphorically employed.

Chaucer's whole possible color vocabulary did not equal the number of words which Miss Lowell had at her command for a small fractional part of the spectrum. The standard colors of his language—the whites, blacks and grays neglected—were brown, red, yellow, green and blue. Dun and fallow were in use, but these, as Dr. Johnson maintained, were barnyard rather than poetic hues. Blo, which Chaucer used once, preserved a doubtful distinction from blue. Purple was a common enough word, but he used it only in translation or with classical reminiscence; except for its occasional heraldic use I should doubt whether Chaucer actually knew what hue it denoted. In addition to these were a few terms which were just beginning metaphorically to be used for colors instead of for dyestuffs and materials; the Wife's scarlet hose must have suggested a fabric as well as a hue to the earliest readers of the Prologue. In fact, any one considering the matter historically must admit that Chaucer was actually as much of a pioneering colorist as Amy Lowell. She coined such compounds as "rose-green" which left our modern conservatives gasping; probably the conservatives of five hundred years ago gasped too when they found Chaucer, under stress of finding six rhymes, once using azure abstractly to mean blue instead of concretely to mean, as every one knew it did, lapis lazuli. Langland and Gower did not do such things, but were content with good old red and green. Chaucer, again, seems to have been the first to use as color words ruddy (except as applied to the complexion), sunnish, citron and rosy. To arrive at a simple term for so common a hue as orange was, however, clear beyond him, so that twice we find the interesting and accurate but ludicrously clumsy circumlocution—"betwixt yelwe and reed."

This constitutes, I hope, a sufficient defense of Chaucer himself, but at the price of a severe indictment of the English of his time. Once more, however, we must not assume that this childlike color vocabulary indicates that medieval England had attained only a childlike state of culture. The world has never seen more highly developed cultures than those of Periclean Athens and Augustan Rome, and yet Sophocles and Vergil were little, if at all, better equipped than Chaucer to express shades of color. These languages of the classical world had adapted themselves for the subtlest play of dialectic or the most complicated legal relations, but they could not distinguish between blue and violet. Plato (to judge from his extant writings) could with difficulty have mastered words for ten distinct hues; for such a common shade as pink Aristotle was forced to coin an awkward "white-red" (λευκέρυθρος). Vergil was little better off; although succeeding to the Greek heritage and able to piece out his scanty Latin vocabulary with borrowings, he could distinguish only a round dozen of colors. He was richest in reds, but besides the general term (*ruber*) was able to denote only a few shades, to be roughly equated with modern English ruddy (*rubicundus, rubens*), orange-red (*rutilus*), rosy (*roseus*), blood-red (*sanguineus, cruentus*) and crimson (*puniceus, purpureus*). Horace, Ovid and Catullus can succor Vergil's vocabulary with only a few unimportant terms.

Two passages from the literature of the highly developed period succeeding

the Augustan display an even comic weakness. When Pliny the Elder, cultured man of the world and eager observer, attempted to describe the varieties of hematite, he stammered like a child. "There are three kinds," he wrote, "red, and less reddish, and half-way between these." Junior in the fourth grade would hardly be allowed such language to-day. Aulus Gellius a few decades later, playing Boswell to a Johnson by Favorinus, lets us see that the Romans of that period themselves were acutely conscious of this weakness. Gellius wrote:

> Favorinus, the philosopher, going to visit Marcus Fronto . . . wished me to accompany him. At his house, in the presence of many learned men, much was said concerning colors and their names, that there was great variety of colors, but that the names for them were inadequate and uncertain. There are more discriminations in the perceptions of the eyes than in names and terms for colors, for to say nothing of their other peculiarities the simple colors of red and green have each but a single name, though many different varieties.

Favorinus, who was the spokesman of this opinion, was, in the symposium which followed, refuted by Fronto, who was able to show that the Latin language by the aid of Greek borrowings could actually distinguish five shades of red. Any modern man in culture comparable to Favorinus or Fronto should be able to mention twenty at least. One is left amazed that in Rome itself "in the presence of many learned men" the question of verbally distinguishing more than one shade of red was subject for argument. For contrast, I may note that recently a group of twenty university students at my request wrote down as many words for shades of red as they could in five minutes. The lowest score was seven, the highest fourteen, and the total, duplication eliminated, thirty-five.

We have wandered a long way from Mr. Perkin, but we are ready now to take the back trail simply by asking the old question, "Why?" How comes it that in our day colors may glow a dozen to the page while in former ages that number would have exhausted the poet's whole hoard? A complete exposition of cause and effect is, of course, impossible; I wish, however, to point out the workings of one important agency, nothing more or less than that old enemy of poetry, science. Our age in nothing differs more from both the medieval and the classical than in our organized and always successfully advancing science. In one way or another it is to this scientific research, beginning in the seventeenth century, that we owe much of the color richness of English poetry. I shall illustrate with three examples, one from each of the past three centuries.

In the month of February, 1671/2, one of the greatest of all scientific experimenters, Sir Isaac Newton, recorded the result of passing a pencil of light into a darkened room and by means of a prism analyzing it into the spectrum. Sir Isaac, if we can accept the famous cat and kitten story, had somewhere in his unsurpassed brain a streak of childishness, and for no other reason apparently than the great tradition of seven, he invented for the spectrum the seven so-called primary colors. Even for these, however, terms were not readily available. "Red, yellow, green, blue," he noted first; then came, as the wording seems to indicate, a striving for a term, and the great brain so apt at voyaging through strange seas of thought alone was hard put to it to produce "and a violet-purple." Followed, one imagines, a rumpling of the divine forehead until there came forth—"together with orange and indico." One notices that instead of naming the colors in logical, scientific order from one end of the spectrum to the other he wrote down those first for which he had definite terms. Purple was a common word of the time, but did not fit exactly, so that

he qualified it with the not yet established term violet.[1] In later writings he became bolder in his use of language, and dropped the purple. Orange and indigo Newton did not quite coin, although before his time they almost always carried the suggestion of the fruit or the dyestuff. But if he did not give the name, he at least supplied the local habitation; violet, orange and indigo thenceforth had their definite places in the spectrum. They became standard colors—a precise image every time one looked at a rainbow. Men since Noah, poets by the hundred, had seen rainbows, but had generally accepted them as the grace of God. Only when the man of science made an artificial rainbow and considered why, other than by divine caprice, orange lay beside red instead of beside blue—only then were definite terms found necessary. In the vigorous scientific controversy which followed certain of Newton's declarations, the names of his seven colors were popularized, or at least became known to men of culture. In the next century with Thompson and Gray they began to work into poetry. Without this aid of science one wonders how Edwin Arlington Robinson could have described his Isolt of the violet eyes, which, so often mentioned, give to her at once the touch of romance and of individuality.

In the eighteenth century one of the most active fields of science was that external and descriptive side of botany and zoology called natural history. In Sweden Linnaeus, in France Brisson and the great Buffon, in Germany Borowski, in Russia Pallas, in England Latham, Pennant, Goldsmith and White—these are only a few of the many who either as investigators or as popularizers furthered the work. Accurate observation in the field of natural history demands a keen sense of color; accurate record of this observation demands an adequate color vocabulary. These writers upon natural history had the color sense, and by sheer force of necessity they made their color vocabulary. They were not always masters of language; their compounding of words was sometimes infelicitous; but, by and large, they accomplished much.

To appreciate the difficulties of the case for an English writer, consider yourself setting out to describe and distinguish 133 varieties of parrot—that gaudiest of birds—with a Chaucerian or Vergilian list of colors. This was approximately the predicament of Latham, for example, when preparing his "General Synopsis of Birds." To write at all he had to be able to distinguish colors, and he did distinguish them. To him violet, which the poets still treated gingerly, was a commonplace. For a while he adopted a half-way attitude on orange by calling it orange-color, but before he got far with the parrots he dropped the idea of the simile to the fruit and wrote simply orange. For Chaucer a parrot would probably have been merely a bird, "yellow, blue and red," or else he would have taken refuge in similes and heraldic terms, as he did in describing Chantecler. But Latham buckled valiantly to the task and his vocabulary flourished. He enlisted the suffix *–ish;* he made use of the homely garden compound of pea-green; he borrowed from the Latin luteous, rufous and fulvous; he ransacked all nature for lilac, brimstone, vermilion, chestnut, ash, cinereous, peach-blossom—any stick to beat a dog, and any word to describe a parrot.

To show Latham's minute observation and—of more interest to us—his color vocabulary, almost any of his descriptions can serve. His thirteenth species, the Blue-headed Parrot, is as good as any.

[1] Violet, in fairly common use in the fifteenth century, later fell into disuse.

The upper mandible is yellow, with a pale ash-coloured tip; the lower of a plain ash-colour; eyes in a naked yellowish skin: above, the plumage is green; beneath yellow green: the forehead inclining to red: the head itself is blue: throat violet, inclining to ash: sides of the neck luteous: hind part of the neck, back, and scapulars, green: the lower part of the back, rump, and upper tail coverts, of a shining green: fore part of the neck, yellow green, lightening into yellow at the sides: from the breast to the tail greenish yellow: wing coverts green: quills green above, the inner webs and tips deep ash: beneath cinereous; shafts black, except that of the first feather, which is whitish: the two middle tail feathers are greenish, verging to blue at the ends: the next the same, but yellow within: and the four outer ones on each side green on the outer webs, luteous on the inner; the webs above black, beneath white; all but the two middle ones tipped with yellow, and the whole tail yellowish ash-colour beneath: the two middle feathers exceed the outer ones by near four inches: legs blueish: claws grey.

In this one passage Latham is able to distinguish twenty shades with some accuracy and to find words for them without undue awkwardness.

Gilbert White, contemporary and friend of Latham, is also of interest because his "Natural History of Selbourne" is one of the few links in English between science and *belles lettres*. With White we see at work the same urge which motivated Latham. He peers over dead specimens or spies upon living ones, seeking to distinguish hue and shade for identification. If his vocabulary was not as varied as his contemporary's, this was probably because he was under the necessity of describing only the respectable fauna of English moor and dale instead of the bedizened denizens of tropical forests. The method was the same, as he poured over a lifeless bird and wrote, "Its *cere* and feet were yellow, and the circle of its eyelids bright yellow. . . . As it had been killed some days, I could make no good observation on the colour of the pupils and *irides*." (Letter 11.) Again, he catalogued on the plumage of a certain lark, a dull-colored bird at best, six shades; here it was dusky brown, there simply dusky, elsewhere tawny, in other parts white, milk-white and yellowish white (Letter 24).

Compared with the naturalists, the leading poets of the same decade show a really lamentable poverty of color. Goldsmith displays less variety than Chaucer; Cowper used neither violet nor orange, and in his many volumes of poetry distinguished hardly a sufficient number of shades to serve for one bird.

But a new generation was at hand. Latham and White both published in the eighties, a decade in which flourished a group of eager boys, ardent lovers of nature, who in a few years transformed English poetry. In the eighties little Walter reveled in the beauties of Teviotdale, young William absorbed nature by the English Lakes, elsewhere were Samuel, Robert, another Walter and two Thomases. In the course of a few years infants were born and named George, Percy and John. Approximately a generation after the great burst of writing on natural history these children grew to manhood and brought their poetry to fruition. The relation of the former to the latter is thus certainly *post hoc*, and also in the color vocabulary at least, I believe, *propter hoc*.

The Romantic poets displayed the most developed use of color in English verse to their time. The Elizabethans were indeed often lavish in the color words, but their terms were in many cases connotative or suggestive rather than distinguishing. Hell-black, heaven-hued, and so forth, have fine poetic possibilities, but would be of little value for the classification of birds. Shakespeare and Spenser did not separate rose and pink, did not use violet or any word but purple for that whole group of shades and could with difficulty (Spenser, I think, not at all) distinguish orange. They were stronger in reds. The Ro-

mantics, on the other hand, equally well supplied with reds, were much better off for the colors farther along the spectrum. Purple, for instance, they supplemented with violet, amethyst, hyacinthine and lilac, not to mention any number of qualifying adjectives, such as deep or faint, coupled to all these.

Two phases of the situation are of special interest. One is that many new color words (olive, pea-green, brimstone, lilac, ultramarine, for instance) previously popularized by the naturalists turn up in Romantic poetry. The other is the use of a developed system of qualifying colors, of which the language had not previously made much use. Even the Elizabethans seldom coupled an adjective with a color or combined two colors. These became, however, favorite devices of the writers of natural history. To return to Latham, we find constant use of combinations like deep-blue, bright-yellow and dull-red, together with simple and complex color coupling such as orange-red, greenish-yellow, yellowish-orange-brown. Combinations of these sorts are characteristic also of Romantic poetry. In Wordsworth alone occur among others deep yellow, dull red, pale blue, together with red-brown, olive-green and black-blue. The immense possibilities of these two systems of modification were first recognized by science under the stress of necessity, and then adopted by poetry.

In the seventeenth century poetry had drawn aid from physics, the most ideal of sciences; in the eighteenth from biology, the most picturesque of sciences, but in the nineteenth its debt was to be owed to the most utilitarian, grimy and odoriferous of all sciences—chemistry. In 1856 a precocious young investigator oxidized commercial aniline with potassium dichromate, and began a brilliant career which eventually gained him knighthood and an article in the Encyclopaedia Britannica. The new compound was a dyestuff producing a brilliant and unusual purple. Possessing acumen for commerce as well as for science, Mr. Perkin patented the process of manufacture, and also borrowed from the French a trade name, *mauve*. Both as a dye and as a word mauve was an immediate success. Two years after its commercial production was begun the word was well on the road to establishing itself; before the end of the century it was naturalized enough to permit the formation of *mauvish*; it is now a standard word in prose and verse; its latest achievement is to attain symbolic value, and to be used in Mr. Thomas Beer's "Mauve Decade" to characterize the last years of the century which witnessed its invention.

But the direct debt owed by poetry to Sir William Henry Perkin is only a small fraction of the indirect one. For, lured by his success, hundreds of eager organic chemists, like prospectors to California a few years earlier, rushed into that vast unexplored region where lay hidden the precious aniline dyes. In 1859 the second dye was perfected—a piercing purplish red. Already the year had seen one study in red blotched at the command of Napoleon III among the vineyards by the Ticino. After this victory of Magenta the second dye was named. Thus by the twists of linguistic fortune a French flower and an Italian town became English colors.

Ever since this beginning the dyeing industry has exercised influence on our vocabulary. Since the development of the aniline derivatives the dyer has had at command a wealth of color such as never before. He and his ally, the fashion-maker, having selected a shade can continue to produce this exact shade as long as demand lasts, and can therefore with advantage and propriety give it a definite name. The result is that now the most complex color vocabulary is neither with the poet nor with the naturalist, but with the dressmaker. A

page from *Vogue* would give Latham names for colors, knife-edged distinctions, which he could not match from all his 133 parrots. Some advertisements from *Harper's Bazar* make Amy Lowell seem as primitive as Chaucer. I mention only a few shades which are now merely technical terms in fashion, but which may some day be material for poetry: Queen blue, navy, orchid, palmetto, athenia, nude, cyclamen pink, flesh, peach, Chinese yellow, monkey-skin, cocoa, Goya red, Alamanda green, Sistine blue, praline. A single page of the catalogue of a mail-order house—surely nothing could be more commonplace—yields among dozens of others Nile green, popcorn, gull, Napoleon, Oporto, cerise, henna. Some of these are glossed, but the glosses themselves presume a highly developed color vocabulary. Nile and Palmetto green are apparently considered standard colors, and not explained at all, although I have not found the latter in any dictionary. Autumn glory is translated as bright henna, and hydrangea as new powder blue, on the assumption, apparently, that these latter shades would be known to every one. Another mail-order catalogue devotes an entire page to a color glossary, listing and describing a total of 336 shades.

Fashion shades and their names are, in short, legion. A single manufacturer advertises seventy, another seventy-two, for one season. Many of these names are, true, ephemeral, to be forgotten by next year; nevertheless, they are definite names for definite shades, and where they fill a want are likely to survive. Let it be recalled that several of our now accepted color words began primarily in fashions—mauve, magenta, lavender and (it would hardly be too much to say) scarlet. Of more modern examples Alice and Navy blue, and Nile green have survived the vicissitudes of years, and may almost be said to have established themselves. Beige came into use some five years ago, and is now such a standard color of reference as to boast rose beige, French-beige and other subvarieties. I have seen the parvenu listed on equal terms with white, blue and green, aristocrats of ten thousand years' standing.

For illustration of how fashion-words have affected the vocabulary of at least the one half of the American nation, let me record a conversation which I recently heard; neither party follows a profession concerned with color:

"Yes, my bridesmaids were in a faint pink, very faint, well hardly a pink at all—a flesh."

"Half of mine were in orchid, and the others in a darker shade, a deep orchid, I guess you would say. Not a purple of course, more like a lavender.

"Lilac?"

"Yes, something like that."

Of all the colors mentioned, Shakespeare and Milton would have recognized only purple. The talkers, to be sure, seem to flounder a little for words, but one must remember that they are attempting to induce a precise image out of the four million possible ones of hue and shade. And to give them their due, they succeed remarkably well. Two hundred years ago, no one, neither philosopher nor poet, would have been able even to try.

While science in the past three centuries has been supplying words, it has also been increasing our vocabulary in more subtle ways. It has undoubtedly rendered us more sensitive to color. Chaucer and his fellows *may* have been keenly alive to hue and shade, but our general experience in such matters would teach us that, more likely, they were not. Without words to emphasize and without need to classify they probably let all reds pass as red and were content. Science, classification, has changed this. To Gilbert White straining his eyes over the dead lark, to the chemist watching the marvelous play of color in his Fehling's test, to the physi-

cian searching through his microscope for the tints which distinguish the eosinophile from the polymorphonuclear, to the housewife matching scientifically dyed thread to scientifically dyed fabric, to the rancher's daughter isolated beyond the last filling station nervously ordering a spring dress from Sears Roebuck or Montgomery Ward, to the very tot in school studying a color chart arranged according to the discoveries of physics, the accurate distinction of color is the business of every-day life.

The very standardization produced by science, so often bewailed as having given the *coup de grâce* to poetry, has also by a curious back-twist really aided poetry. As long as a certain shade of yellowish pink existed only in the flesh of an apricot, in a momentary shade of the morning sky and in an occasional gown, language could never afford to have a special word for it. But when by modern methods of color production the same exact shade may glow from a million scarfs in one month, a word becomes to some necessary and to all convenient, and apricot is thereupon a color as well as a fruit. Thus the poet gains a fresh aid to blazon forth anew that oldest of poetic subjects, the rosy-fingered Aurora, and so display his contempt for science, destroyer of beautiful myths.

Truly, great is science, and her name is above all kings. We still stammer, we are little better off than was Chaucer for descriptions of smell; science has as yet done little to explain and codify. There is as yet no smell spectrum. If there ever is, we may predict that words will be called into being, and with words poetry. Christopher Morley will no longer be forced to:

> wonder why the poets tell
> So little of the sense of smell.

Just as Napoleon, greatest enemy of perfidious Albion, could not march his battalions against Wellington without the help of English shoes, so poetry is glad to gain new vigor by the aid and succor of its age-old mortal adversary.

THE SCIENTIFIC STUDY OF HUMAN BIOGRAPHY

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THE students of the historical, humanistic, social and physical sciences are united in a common interest in human biography. They want to understand the factors which favor high productivity in philosophic speculation, scientific investigation, literary creation, economic enterprise and political management. They would like to know how, within the same field of activity, "temperamental" and "environmental" influences combine to produce different constellations of traits and interests. The ever-present problem is to account for the appearance of and the differences manifest in Shakespeare and Goethe, Descartes and Kant, Newton and Einstein, Bismarck and Napoleon. Or, more generally, the task is to isolate the operative factors in the determination of typical views of the world and typical levels of creative activity.[1]

Many streams of investigation have convincingly shown that a human life, viewed at any given cross-section, is the outcome of formative factors of many kinds. The cultural *milieu* leaves its mark on the speech, morals, manners, tastes, ambitions and loyalties of the individual. The phantasy life of the person gives him a private world which distinguishes him from his fellows in the same cultural environment. No individual can be completely defined as the phenomenon observable at the intersection of culture planes; it is a commonplace that members of the same family, exposed to the same religious, racial, partisan, national, educational and occupational influences, display wide differences in traits and interests. The physiological and anatomical make-up shows several typical deviations within the range of the "normal."[2] Differences in glandular function may make puberty crises, menstrual cycles and climacteric changes more serious for one than another. Physiological and anatomical facts, such as shortness or tallness, fatness or thinness, may expose the person to respect or contempt in specific cultures.[3] The neurological and intellectual coordinations of individuals differ very markedly from one another. There are important differences in such fundamental processes as those of perception, some individuals retaining eidetic imagery throughout their adult lives. Pathological elements in the ordinary organic processes are not to be underestimated. Some types of disorder bring ascertainable consequences for the efficiency, mood and preoccupation of the victims. The pathological changes associated with senility are especially significant in politics, where old men occupy high diplomatic, administrative, legislative and judicial posts. The psychopathological disturbances are particularly prominent in many active and productive lives. Medical psychology has recently come to stress the importance of repressions in the production of neurotic symptoms, neurotic character traits, psychotic symptoms and perversions.[4]

[1] One may refer in passing to the work of Dilthey, Spranger, Klages, Jaspers and their circles in this connection.

[2] A readable, succinct summary is that of E. Miller, "Types of Mind and Body," New York, 1927.

[3] H. Hoffman has outlined a method of approach to the study of heredity factors in his "Das Problem des Charakteraufbaus," Berlin, 1926.

[4] An evaluation of existing personality documents is in my article, "The Problem of Adequate Personality Records: A Proposal," *American Journal of Psychiatry*, May, 1929.

That the writing of human biography is in an unsatisfactory plight is manifest in the omissions and mistakes which are to be found in the current output. In the universities, human biographies continue to be written under the sole jurisdiction of separate departments, often ignoring the interpretative concepts which are successfully used by men in other departments of the same institution, or applying them in amateurish fashion as mere figures of speech. This is especially the fate of such psychopathological terms as "complex," "repression," "sublimation," "compensation."

The obvious escape from the difficulties of the present situation is by way of a procedure which familiarizes the apprentice biographer with the chief technical tools of the major fields which converge upon the interpretation of human reactions, and to give him the benefit of sustained technical criticism in applying them to a definite case.

It is scarcely feasible for the student to shop around among the departments of internal medicine, neurology, psychiatry and psychopathology, psychology, anatomy and physiology, besides the departments of social science, history and the humanities of the university. If the student attends clinical demonstrations in internal medicine he may learn something about the symptoms of many diseases, but all that is directly valuable to him is the recognition of those disease conditions which have been demonstrated to have special effects upon the mental state of the sufferer. Such correlations emerge as medical psychology develops. It should be possible to render the current data readily accessible through lectures, demonstrations and bibliographies. Moving-picture films may be developed to show how the diagnosis is made, and the psychological effects of the disease upon the patient.

The prominence which has been given to pathological and physical scientific conceptions in this brief statement does not mean that the chief aim of biography is to become pathography. Of pathographies there are many, since Möbius introduced some discipline into the field.[5] Biography is a larger field, requiring the analysis and resynthesis of the significant features in the individual's total history.

The central nucleus of those interested in the problem of more adequate human biographies might very well constitute themselves into an institute of human biography, composed of a historian, sociologist, political scientist, economist, jurist, humanist, historian of science, historian of philosophy, psychiatrist and psychopathologist, doctor of internal medicine, geneticist and psychometrician. Temporary consultants could be attached to the central nucleus as specific studies warranted.

Since the modern university makes so many demands upon the time of its members, any task which is not institutionalized is prone to be neglected. It is therefore desirable that the chief centers of learning both here and abroad develop mechanisms of the type proposed. Each individual institute might guide the research of both pre- and post-doctoral workers.

If the retrospective interpretation of men's lives is to be kept abreast of specialized scientific progress, the development of such a converging attack seems to be imperative.

[5] See the recent summary of this entire literature by Wilhelm Lange-Eichbaum, "Genie-Irrsin und Ruhm," München, 1928.

THE SPARROW-HAWK'S FIRST FLIGHT

By RALPH E. DANFORTH

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To see it throw itself into the air before it had had any chance to practice flying gave a thrill worth long and patient efforts. Reared in a hole high up in a great tree the young sparrow-hawks could not even stretch their long wings adequately to give them what we would consider a conception of what flight would be like. The five young hawks had taken turns looking out of the round hole to see a small portion of the world into which they were soon to thrust themselves upon untried wings. They had seen their parents fly with consummate skill and speed. They themselves had remained crowded together in a hollow; jostling one another for the large insects brought to them; crying tremulously with insatiable appetite; clambering over and falling back upon one another; exercising indeed but not flying. Could a moment come for each one when it would risk a twenty-eight-foot fall to earth, throw itself with closed wings out of a round hole and fly to a neighboring tree? That was what I wanted to see with my own eyes.

The American sparrow-hawk, *Falco sparverius sparverius* L., is not as closely related to the sparrow-hawk of England as it is to the hobby, merlin and kestrel, which are true falcons. Our American sparrow-hawk is a small falcon. Early in April a pair selected a hole in a large elm near our home and forced out the starlings which had used it ever since the flickers had made it and reared a single season's offspring in it. Our local flickers have to carve laboriously a new hole every season because long before they return the next spring the starlings have been living in it. The pair of sparrow-hawks, however, had no regard for the starlings' desires and took possession and kept possession even during two distressing snow-storms that came before the month of April had ended. I well remember their sitting near the nest-hole, feathers fluffed out, through two long, tedious northeast snow-storms, storms during which many robins and bluebirds perished for lack of food.

I kept an interested eye on their activities through April, May, June and the first half of July, but will not take your time to describe these. Early on July 18 one came out; his parents were feeding him in the top of a neighboring elm. I resolved to try to see the next one leave the hole, but in this I was to be disappointed, for although I watched many hours that day, and began my vigil at daybreak the next morning, Number 2 slipped out in a moment when I was otherwise engaged. Morning, afternoon and evening I watched, for there were others to follow, and some of them seemed about on the point of leaving. They would lean far out of the hole until it seemed as though they would fall. The hole opened somewhat downward, as it was on the under side of a huge limb, a little above the point where the main trunk forked to form the crown. The birds took turns at their circular window, sometimes gazing out from far within, sometimes with their guinea-pig faces framed by the opening, sometimes with half or more of the body projecting. Their curious bills were so small and down-curved that they appeared not to have any beak, while the bizarre markings on face and head made them resemble strange mammals rather than birds. When the bird looked down-

ward revealing the back of the head with its two black spots surrounded by buff-colored rings it seemed to have owl's eyes in the back of its head. Sometimes they were silent, with head bobbing up and down in a half timid, half menacing way. Again they were noisy, tremulously calling their parents for food. From my screened porch below or from my second-story window I could watch them clearly.

The parents were always wild and suspicious if one came out near the tree. On the morning of July 20, 1929, I again arose at the song of the robin and trained my field-glasses out the open window, propping them so that the hole in the elm would be in the center of vision whenever I might choose to lower my eyes to look through them. Most of the time I preferred to watch with unaided eyes. No sign of activity among the sparrow-hawks was yet to be seen. The parent birds were doubtless roosting not far from the two young which had left the nest. Long before the sun gilded the sky, however, the parents were actively feeding the young, both those outside and those within the hole. Soon they stopped feeding those in the hole, except at long intervals, feeding the liberated birds more often. The most active bird left in the hole had a very light breast with scarcely any streaks upon it. I thought surely this would be the next to leave. In fact, I had thought it would leave the day before. It was the one to lean farthest out and to spend more time than its share in so doing. But a less assertive bird with dark stripes on its breast replaced it at the window for a few minutes, then suddenly and silently flew to an elm eighty-one feet away, catching itself with difficulty in some small twigs at the base of the leafy crown of the tree. Instantly a parent bird appeared from some tree-top and followed it closely to make sure that it alighted successfully. Reassured that all was well with the young one the parent departed as silently as it had come.

After a few minutes' rest the young one began climbing up to larger branches. It seemed to gain strength rapidly. Resting and climbing by turns it soon gained the top. In climbing it both walked and hopped, using the wings freely.

In half an hour the light-breasted one launched out and flew strongly and unattended to an elm 138 feet distant, alighting in the great fork at the top of the trunk, a point higher up than the hole the bird started from. It too shortly began climbing the tree. Soon Number 5 left the hole, but not until it had tried to start but changed its mind after it had put its left wing fully out of the hole. It was the only time I had seen one of those birds with a wing out of the hole before they left the hole for good. It with difficulty pulled that long wing back into the hole after it. Then it came out again, doubtless uneasy at being left all alone for the first time in its life, and it too flew 138 feet, catching the leafy frond surrounding the hole, some ten feet below the top of the trunk.

None of the young returned to the hole. They may never enter one again until they set up housekeeping for themselves. Toward noon the mother bird did enter the forsaken hole just for a moment, possibly from idle curiosity.

It is unsafe to ascribe human motives to a bird or other animal. We often err in reading the motives of other human beings. But if all creatures have common instincts and ancient hereditary backgrounds, we may sometimes be right when we guess what goes on in the mind of a lower creature.

What does the first flight mean to the little falcon that has never been out of the hole? From many observations of these young sparrow-hawks I gained the impression that they are very sordid and

selfish. When their instinct to master the air becomes strong enough to overpower their instinctive fear of falling, the thrill they get is probably more physical than intellectual. They have, indeed, been training their truly wonderful eyes on earth and sky, on objects near and far, for a long time before they fly, and can see much better than any human beings, and there must be added satisfaction when they can see from a tree-top much more than from the nest-hole. But fancy that *you*, and not the sordid bird, were brought up in a hole in a tree, along with various brothers and sisters of about the same age, the size and form of the bird, but possessing your human intelligence and poetic fancy; what would the first flight mean to you?

The change from life in the hole to life in the open world and sky comes with the suddenness of death. From the time of your earliest memories until the instant you darted forth upon the free air your whole life was crowded, with those of your brothers and sisters, in a small hollow in a tree, and poorly lighted from a still smaller opening to the outside world. After long waiting and growing and scrambling for food brought by those all-providing parents that came and went on silent, speedy wings, you began to clamber up to peer out of that hole of mystery through which food and parents alike had always come. What dreams and thoughts you would have about that bountiful outside world, stretching on and on apparently without end or limit. As your strength increased you would lean out of the opening, and, with your head and eyes well out from the tree, you could fancy yourself almost free; yet always your view would be so limited to that one center, and so cut off by the tree itself and by the many other fixed objects. You could not feel the things you saw, or reach them. What you saw would mean but little to you, but all the while your eyes would be training and your wing muscles growing. The problem of exercising the wings in cramped quarters would be difficult. The wings would be too long to move as in flight. If you are a human being who worries you would worry about the proper preparation for that first flight. When the time came for you to lean far out and spring into the air the impulse would need to be very strong, and you would say it took a lot of faith. It would, indeed, be like the faith to die and believe that it would be the portal of a supremely larger life. You never would have tried it. You had caught only broken glimpses of it from afar. The actual proof that the wings would work would come only when it was too late to draw back into the dark hole. It would be fly or—what? You knew not what, in case you did not fly.

Then the soft, elastic air buoyed you up. With a swiftness you had never known before you sped through space. You could not keep this up long. You must alight somewhere. The inviting green of the elm fronds offer safety and rest. Yes, you feel them with your feet. You are safe. You have conquered thin air. The sky and all beneath it is yours. No longer will a small hole restrict you. No longer will its rough-hewn walls confine you and blot out your vision. You will not enter that narrow life again, not even to sleep. You will climb, in a few moments, to higher twigs. Then climb again, and yet again, until you are comfortably perched in the very top of that great and massive tree. The warm sun beats upon your whole being. Overhead nothing but the sky limits you and your vision. No half-decayed wood to roof you over. No quarrelsome companions to crowd you against cabin walls. If they bother you now there is all the universe around you. New sights in infinite variety surround you

on all sides and above and below. You have graduated from a narrow life to one of wide immensity.

We might compare the experience to the change of caterpillar to butterfly, but it would not be analogous, for the long wait in the pupal stage is so different from the fraction of a second that it takes to spring into the air when already leaning far out into it. It might be likened to the germinating of a seed and its marvelous change into a plant, with all its larger life. But that process is again very slow—a gradual transformation. I can not think to what to liken that sudden, instantaneous change from life to larger life, from a cramped and very confined life to life of unlimited possibilities, unless I compare it with death.

The little falcon must fear the leap. He takes it.

THE WINTER WREN, HIDDEN ARTIST OF SONG

By RALPH E. DANFORTH

CHESTERFIELD, MASS.

THE winter wren is a true bird-lover's bird. Many people will not know him really well. He is not rare but eludes them. He is small and dark and continually crawling under rocks, logs, sticks and whatever vegetation may be around him. Yet he is uniquely beautiful in form, manner and marking. His song is his supreme charm. Whoever hears this song and learns to know it has enriched his life. For all time my store of joy is greater because the winter wren's song has added to it. A trip to the summer haunts of the winter wren will prove a good investment if the lover of sweetest sounds and melody succeeds in hearing the song of the winter wren.

Thoreau heard and described the song when on a trip in the White Mountains, yet he probably never knew what bird had sung that song. He was unable to follow up the sound, having lamed himself. Yet description and habitat fit the bird so well that those who know the winter wren agree that such was the unknown bird which so charmed this great man of the wilderness.

Burroughs calls the winter wren a "marvelous songster, in speaking of whom it is difficult to avoid superlatives," and adds:

> He possesses the fluency and copiousness for which the wrens are noted, and besides these qualities, and what is rarely found conjoined with them, a wild, sweet, rhythmical cadence that holds you entranced. I shall not soon forget that perfect June day, when, loitering in a low, ancient hemlock wood, in whose cathedral aisles the coolness and freshness seem perennial, the silence was suddenly broken by a strain so rapid and gushing, and touched with such a wild, sylvan plaintiveness, that I listened in amazement. And so shy and coy was the little minstrel, that I came twice to the woods before I was sure to whom I was listening.

Florence Merriam Bailey writing of first hearing the song of the winter wren called it "the event of the summer in the woods. Full of trills, runs and grace notes, it was a tinkling, rippling roundelay."

These few quotations show that one is in good company when praising the winter wren. Yet few indeed are those who know him well. Each spring and summer the winter wren invites you, reader, to join the company. Pleasanter invitation never sounded through the woodlands.

This dark little cinnamon-brown bird first made himself known to me when I was a small boy in southeastern Pennsylvania. His dapper appearance, the black bars across his sides and belly, his

mouse-like habit of creeping under brush-piles, rocks and overhanging banks of brooks captivated my boyish fancy. But I did not hear him sing until years later in the high hills of New England. I have only heard the winter wren sing in the spring and early and middle summer. In the higher parts of the Alleghanies he does nest as far south as North Carolina, but at ordinary altitudes he is not often found nesting and singing south of Massachusetts. Further south he livens the winters with his distinctive chirp and sprightly activity.

Interest in this little bird makes one want to know more about his family. There are hundreds of species of wrens in the world, some in the Old World but most of them in the tropics of the New World. This is unusual, for most bird families represented in both the Old World and the New have more species in the Old World. It would be fascinating to follow these many wren species in tropical America. We have but few species in the United States, fewer still in Europe.

One who knew only the house-wren and the short-billed marsh-wren would be surprised to know that some wrens really can sing the sweetest of music. Bewick's wren is an excellent singer, and a Carolina wren wakened me with the regularity of a clock one winter in the mountains of North Carolina. It was a joy to be wakened by sounds so clear and strong and peaceful. I have ever since loved the song of the Carolina wren. It is one of my favorite bird-songs. Our ancestors in England probably knew but one species of wren, but it was a sweet singer and often sang in winter. They called some other small birds, as kinglets, "wrens" also.

In Porto Rico I found no wrens. Several of our northern warblers go there in winter, but the odd little tody, with its short tail and long bill, is the most wren-like in habits of all the native Porto Rican birds. Its back is as green as a leaf and its throat is red.

To know the winter wren through and through find him in his northern breeding range or in his mountain fastnesses. Hear that soul-stirring melody and follow it, if you can, to its feathered source. This past summer several have been singing in Chesterfield, Massachusetts. In the woods beyond the "Gorge" one sang through the spring and early summer, and wandered frequently as far as the "Bend" where many swimmers enjoyed its songs as an added touch of wildness in the wooded surroundings. They often asked what was that "canary-like" song so much sweeter and wilder than any canary song. None knew it until told. As far as I could learn none followed it to its author. I was glad they did not disturb it. We heard them also this summer on Mount Monadnock in southern New Hampshire. I saw one there as late as the end of September, scrambling over and under huge rocks in a rocky ravine.

The winter wren combines two strongly contrasting types of individuality. It is exceedingly self-contained, retiring, secretive, yet it pours forth a wealth of song for the world to enjoy which stirs the souls of all hearers. It gives with a prodigal heart of its stored-up wealth gleaned from heaven's sunshine, woodland fragrance, crystal rocks and crystal springs. It gets inspiration from hundreds of wild associates, odd or beautiful. It breathes ever the purest air, it sees always the most beautiful trees. It associates continually with the flowers of God's creation. Stars at night pour down their benediction upon this sprite of the wild. Storms contribute their primal vigor to its wild song. Sunlight caresses the winter wren with gladdest touch. These enter into its song. Clear sweetness and energy and joy are its music. From the fulness of a royal heart its throat pours forth melody.

If the winter wren is a recluse in the wild, it is continually gleaning treasure to offer the world in its song. Only the best of what it receives comes out for others to enjoy. Industriously it collects from a hundred sources, beauty, nourishment, light, color, interest, fragrance, and when these have been thrice refined this generous little being fills the woodland air with them.

But, one may ask, how many can hear the song thus sung in the wilderness? Should the bird not be brought into metropolitan concert halls? The most picturesque portions of the wilderness are the only fit setting for that song. Shall we bring the planet Venus into man-made halls, or view it in the sky? So the place to hear the winter wren is in the limitless open. In nature as God made it one may hear this song as God's creature makes it. Leave your cities and your buildings and your cars behind when you seek the winter wren. Leave your cares and your finances, your foibles and regrets. Leave your jealousies and aches. Just go. Go in search of a rare soul, bigger, perhaps, than yours, though it be tied to a body so tiny. Go where the hermit thrush sings and hemlocks are fragrant. Where flowers and ferns and mosses grow in wildest abandon. The air is purest where the winter wren sings. Light is most sparkling there. It is the place where peace abides. Hear him, see him, know him and carry back something fine and abiding which was not in your heart before.

THE PROGRESS OF SCIENCE

THE ANNUAL MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE annual meeting of the American Association for the Advancement of Science and associated organizations will be held at Des Moines, Iowa, from Friday, December 27, 1929, to Thursday, January 2, 1930. This will be the eighty-sixth meeting of the association and the first to be held in Des Moines. It will probably not be as large as some recent annual meetings but the main fields of science will be well represented and this annual week of American science will be a very full one. All who are interested in the advancement of science and education are cordially invited to attend any of the sessions devoted to the reading of papers. A large number of lectures and addresses of general interest will be given and the exhibition of scientific apparatus, materials and books will be very attractive.

The Des Moines meeting will be held under the presidency of Dr. Robert A. Millikan, director of the Norman Bridge Laboratory of Physics of the California Institute of Technology. Dr. Millikan will give a public talk in the Shrine Temple on Sunday afternoon, his subject being "The Alleged Sins of Science." The retiring president of the association this year is Professor Henry Fairfield Osborn, eminent paleontologist and educator, president of the American Museum of Natural History, New York City, who will be the main speaker at the association's opening session in the Shrine Temple on Friday evening. Professor Osborn's address will be on "The Discovery of Tertiary Man." The annual Sigma Xi lecture will be given on Saturday evening, by Dr. George H. Parker, professor of zoology at Harvard University, who will speak on the general aims of men and women of science. Addresses will be given by the retiring vice-presidents for the several sections of the association. The Josiah Willard Gibbs lecture, of the American Mathematical Society, will be given on Monday afternoon by Dr. Irving Fisher, of Yale University. The Committee of One Hundred on Scientific Research is arranging a symposium on the economic status of research workers.

The preliminary announcement of the Des Moines meeting makes up most of the issue of *Science* for November 29, which presents many details about the meeting, including instructions regarding reduced railway rates for those who attend. It contains information about the program of each of the sections of the association, including the societies that are to meet with it this year. Those who do not receive the official journal, *Science*, may secure free copies of the preliminary announcement by addressing the permanent secretary's office, Smithsonian Institution Building, Washington, D. C., as long as the supply lasts. The general reports of the meeting are to be published in two special issues of *Science* for January 24 and 31, and free copies of these may be secured in the same manner.

The Press Service of the American Association is making arrangements by which scientific news from the meeting will be readily available to newspapers and news agencies, and a number of radio talks by leading scientists are to be broadcast from Des Moines in the meeting period.

DR. HENRY FAIRFIELD OSBORN

RETIRING PRESIDENT OF THE AMERICAN ASSOCIATION, WHO WILL GIVE THE PRINCIPAL ADDRESS AT THE DES MOINES MEETING. DR. OSBORN IS PRESIDENT OF THE AMERICAN MUSEUM OF NATURAL HISTORY AND RESEARCH PROFESSOR OF ZOOLOGY AT COLUMBIA UNIVERSITY.

THE SHRINE TEMPLE AT DES MOINES

WHICH WILL SERVE AS THE HEADQUARTERS OF THE ASSOCIATION. THE AUDITORIUM HAS A SEATING CAPACITY OF FOUR THOUSAND PEOPLE.

DES MOINES AS A PLACE OF MEETING

DR. D. W. MOREHOUSE, president of Drake University and chairman of the local committee, writes that the first Des Moines meeting of the American Association for the Advancement of Science is an occasion of great moment to the State of Iowa. He says that every scientific worker or teacher has reserved the dates December 27 to January 2 for the past three years, looking forward to this meeting with great enthusiasm and anticipation. The Iowa Academy of Science has fostered the project with untiring energy and timely assistance. The citizens of Des Moines are said to count it the most significant gathering they have ever had the honor to entertain. The Chamber of Commerce, through the secretary of the Convention Bureau, has actually made the meeting possible, first through its financial support, but even more significantly by its enthusiasm and personal work during the last three months.

Des Moines is a city of diversified interests. It is not primarily agricultural, industrial or commercial, but it is a center of education and culture. Some years ago an eastern visitor expressed his surprise that he found Des Moines not a western agricultural town, but a center of culture and education. A European traveler, B. Ifor Evans, in his book, "Encounters," writes: "The unexpected gives the element of fun to life; it shows the greatness of the pat-

DR. ROBERT A. MILLIKAN

PRESIDENT OF THE AMERICAN ASSOCIATION. DR. MILLIKAN IS DIRECTOR OF THE NORMAN BRIDGE LABORATORY OF PHYSICS AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY.

tern of the game. I remember one night in the Middle West coming to the town of Des Moines in the State of Iowa. And in my folly I had expected the men of Iowa to talk of corn, mighty and arrogant corn, taller than Babel. Instead a man came out to meet me at Des Moines and took me to an observatory and showed me the stars. 'That brown chocolate smudge,' he said, as I looked down the telescope, 'that is a star which is being born.' . . . It had taken years for the light of that chocolate smudge to reach the world. For a moment one seemed to rise out of the Middle West, to stand above earth, to be at rest in the mind of God. . . ."

Des Moines has entertained some of the largest national conventions, such as the National Education Association, the National Physical Education Association, the Imperial Council of the Mystic Shrine, the Grand Army of the Republic, the National Conference of Social Workers and the Lions International.

The Fort Des Moines Hotel is the general headquarters for the association. It is just three blocks from the Shrine Temple, which houses registration, exhibits and all general session lectures. The section headquarters are in the five leading down-town hotels. The sections A—Mathematics; B—Physics; C—Chemistry; D—Astronomy; H—Anthropology; I—Psychology; K—Social and Economic Sciences; L—Linguistics and Education, and M—Engineering, have selected for their headquarters the Fort Des Moines Hotel. Section F—Zoology, and affiliated organizations have chosen Hotel Savery. Section G—Botany, and Section F-G—groups related to both Zoology and Botany, will be quartered at the Chamberlain Hotel. Section E—Geology and Geography, has chosen the Brown Hotel. Section O—Agriculture, will have headquarters at the Randolph Hotel. Section N—Medical Sciences, will be located in the Commodore, a beautiful apartment hotel in the residential section of the city.

THE FOYER OF THE SHRINE TEMPLE

These headquarters, with the exception of Section N, are all within easy walking distance of each other and of the Shrine Temple. Most of the section programs are held in their respective headquarters, except in the case of joint sessions where larger accommodations are required, and even these will not be over five blocks from any one headquarters.

All the general session lectures will be held in the Shrine Temple, one of the most beautiful auditoriums in the west. The main hall will accommodate over

THE DRAKE UNIVERSITY MUNICIPAL OBSERVATORY
WHERE THE SESSIONS IN ASTRONOMY WILL BE HELD.

four thousand people. The exhibits of the association will occupy the basement, and the beautiful lounge, adjoining the auditorium and having easy access to the basement, will be used for the association reception.

The local committee has tenaciously held to the idea of centralizing the meeting so that all who attend will have the opportunity of seeing other workers in their fields and hearing a diversified program. There are a few exceptions, however, to this arrangement, notably part of the program of Section G—Botany, will be at Iowa State College, located thirty-seven miles north of Des Moines, and Section D—Astronomy, will hold an afternoon session at the Drake University Municipal Observatory, in the western part of Des Moines.

A new departure for the Des Moines meeting is a number of non-technical lectures for the general public and the school pupils. It is hoped that this will increase popular interest in science by allowing the leaders and men of scientific accomplishment an opportunity to disseminate the results of science to the general public and the younger generation who will carry on the work of the association. Extra-mural lectures have been arranged in some of the leading cities of the state, affording those who can not attend the meeting an opportunity to become familiar with the work of the association.

THE CENTENARY OF THE DEATH OF THOMAS YOUNG[1]

One hundred years ago there died in London one of the most versatile men of all time, Thomas Young, M.D., F.R.S., one of the eight foreign associates of the National Institute of France.

His parents were Quakers, and he maintained throughout life strict adherence to the moral principles of that sect, though he relinquished the external forms as unimportant and a hindrance to social contacts. His maternal great uncle, Dr. Richard Brocklesby, was a leading London physician. When his nephew was eighteen years old the doctor introduced him to the inner circles of social and literary metropolitan life. His social success was immediate, and he remained to the end of his life a brilliant member of London society. He studied medicine at London, Edinburgh, Göttingen and Cambridge, commencing practice rather late in life. His uncle at his death left him his town house with his library and paintings and a considerable fortune in money. He became physician to St. George's Hospital, a post which he held throughout his life.

During the first two years after commencing practice in London he was professor of natural philosophy at the Royal Institution. The lectures he delivered there were published in 1807 in two large folio volumes which were for years a standard work.

As a boy he was unusually bright, having learned to read by the age of two years. He had a remarkable memory and great aptitude for learning languages which he mastered with precision. At the age of fourteen, on being asked, probably in a patronizing manner, by one of his uncle's friends to write for him a copy exhibiting his excellence in penmanship, he administered a gentle rebuke by writing in excellent style a copy in *thirteen different languages!* Before he was twenty-one he had produced a work on the eye which resulted in his election to fellowship in the Royal Society.

He was fond of athletic sports, particularly of equitation, in which he ex-

[1] A more extended paper, read before the Thomas Young Memorial Meeting of the Optical Society of America at Ithaca, New York, October 24, 1929, will be published in the *Journal* of the Optical Society of America.

THOMAS YOUNG
1773–1829

celled, and was an accomplished musician and art critic. Although an excellent physician and writer of medical works, he is best known for his work in physiology and in physics. He made a series of remarkable measurements of the eye and founded the theory of color vision later extended by Helmholtz and held in high regard to the present time. He applied his talents to an investigation of the dynamics of the circulation with excellent result. The student of elementary physics soon learns of Young's Modulus of elasticity, but he is best known for having revived the undulatory theory of light and for devising crucial experiments on diffraction in support of this theory. The theory of these experiments he worked out with consummate skill.

He was frequently asked to serve on commissions appointed by the government to investigate and report upon scientific questions of public importance, and for many years he was superintendent of the *Nautical Almanac* and secretary of the Board of Longitude. He wrote learned treatises on the theory of tides and on correction of ships' comtary of the Board of Longitude. He was the inventor of the revolving drum chronograph still in universal use. At the request of one of the large life insurance companies he undertook extensive actuarial studies.

An achievement which illustrates particularly well his remarkable versatility, because so far removed from his better-known scientific activities, was the discovery of the key to the interpretation of the Egyptian sacred characters or hieroglyphics. Visitors to the British Museum may still see the famous Rosetta Stone on which is engraved a proclamation written in Greek, in Coptic and in hieroglyphics. It might seem an easy matter to translate a passage accompanied by two ready-made translations, but the hieroglyphics are a species of picture-writing, and it was not then known what language, if any, they represented. Young determined that they had in certain circumstances phonetic values and laid the foundation for their more complete understanding.

Of all his successors the one best qualified to pass upon his merit was Hermann von Helmholtz, himself famous as physician, physiologist, mathematician and physicist. In his popular lecture on vision Helmholtz says:

> He was one of the most keenly intellectual men that has ever lived, but he had the misfortune that his sagacity too far surpassed that of his contemporaries. They were amazed at him, but could not generally follow the keen flights of his combinations, and so the bulk of his most important thoughts remained buried and forgotten in the great folios of the Royal Society of London until a later generation, by gradual progress, rediscovered his discoveries and satisfied itself of the correctness and convincing power of his conclusions.

Athlete, musician, connoisseur of art, classical and oriental scholar, mathematician, actuary, physicist, physiologist, physician; at the end of fifty-six years of incredible activity, when facing the end, he appraised his life, and it hardly surprises us to learn that he found in its record nothing to regret.

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THE INSTITUTE OF HUMAN RELATIONS AT YALE UNIVERSITY

WITH the opening of the academic year at Yale University, marked progress in the development of the Institute of Human Relations is reported. The institute is to be a center for research in biology, psychology and sociology. All members of the staff will also hold appointments in the fundamental departments of instruction, so that the institute will be closely knit to the university as a whole and will serve as a means of correlating the work in the various pure and applied fields of science dealing with human life. Its primary purpose is in fact the stimulation of cooperative research so that the barriers which have arbitrarily separated related disciplines may be broken down. It is believed that many impediments to progress in the understanding of human conduct may thus be removed. Through the close affiliation of the institute with the professional schools, such as medicine, law and religion, it is believed that the training of men in these fields may be broadened.

A number of university appointments bearing on the work of the institute have already been made. Dr. William Healy and Dr. Augusta F. Bronner will commence this year a study of the family factors in delinquency. In Boston, New Haven and Detroit, groups of families, members of which have been in contact with the juvenile courts, will provide the material for the study.

Dr. Edward C. Streeter, who has been appointed visiting professor of the history of medicine in the Yale School of Medicine, will take part in a broad study of medical organization. Dr. Walton H. Hamilton, of the Yale School of Law, will supervise the economic aspects of this study which has been authorized by the American Medical Association.

Dr. Edgar Van Norman Emery, former chief of the Los Angeles child

guidance clinic, has been appointed to the staff of the department of psychiatry and mental hygiene, and will have a particular interest in the work of mental hygiene in the college which was started some three years ago. Clark Leonard Hull, former director of the psychology laboratory at the University of Wisconsin, has been made professor of psychology.

A survey of European personnel in psychology and neurology was recently made by Dr. Milton C. Winternitz, dean of the Yale School of Medicine. Among the appointments which have followed is that of Dr. John F. Fulton, who is now at Oxford with Sir Charles Sherrington, world-renowned physiologist. Dr. Fulton will be associated with the institute in the field of neuro-physiology.

Construction has been commenced on the institute building which is to house the following already existing university units: Department of psychiatry and mental hygiene; division for research in economics, sociology and government; graduate division in psychology; child development research division. The staff in psychology includes, among others, Raymond Dodge, Arnold Gesell, Clark Wissler, Robert M. Yerkes and Arthur H. Ruggles.

The building is to cost $2,000,000, of which $500,000 has been given by the General Education Board and $1,500,000 by the Rockefeller Foundation. The following gifts have been made by the Rockefeller Foundation for the work of the institute: For the educational program in psychology, $50,000 a year for ten years; for the maintenance of patients in psychology, $50,000 a year for ten years. The Laura Spelman Rockefeller Memorial has given $150,000 a year for ten years for social science research, for psychology research and for child development research. The Commonwealth Fund has now provided $50,000 a year for the work in mental hygiene.

The Institute of Human Relations, with the Yale School of Medicine, the Yale School of Nursing, the New Haven Hospital and Dispensary, constitute what is termed the *Human Welfare Group*. For the development of this group a program requiring $15,500,000 was outlined last February, and $5,600,000 of this amount must still be obtained, according to reports from the university.